# Migrating bats
# at the southern North Sea

Approach to an estimation of migration populations of bats at the southern North Sea

Limpens, H.J.G.A., S. Lagerveld, I. Ahlén, D. Anxionnat,
T. Aughney, H.J. Baagøe, , L. Bach, P. Bach, J.P.C. Boshamer,
K. Boughey, T. Le Campion, M. Christensen, T. Douma,
M.-J. Dubourg-Savage, J. Durinck, M. Elmeros, A-J. Haarsma,
J. Haddow, D. Hargreaves, J. Hurst, E.A. Jansen,
T.W. Johansen, J. de Jong, D. Jouan, J. van der Kooij,
E.-M. Kyheroinen, F. Mathews, T.C. Michaelsen, J.D. Møller,
G. Pētersons, N. Roche, L. Rodrigues , J. Russ, Q. Smits ,
S. Swift, E.T. Fjederholt, P. Twisk, B. Vandendriesche &
M.J. Schillemans.

2016/2017 - Technical Report Zoogdiervereniging (Dutch Mammal Society) in collaboration with Wageningen Marine Research

# Migrating bats at the southern North Sea

## Approach to an estimation of migration populations of bats at the southern North Sea


| | |
|---|---|
| Rapport nr.: | 2016.031 |
| Datum uitgave: | Maart 2017 |
| Status | Definitief 08-03-2017 |
| Authors/contributors: | Limpens, H.J.G.A., S. Lagerveld, I. Ahlén, D. Anxionnat, T. Aughney, H.J. Baagøe, , L. Bach, P. Bach, J.P.C. Boshamer, K. Boughey, T. Le Campion, M. Christensen, T. Douma, M.-J. Dubourg-Savage, J. Durinck, M. Elmeros, A.-J. Haarsma, J. Haddow, D. Hargreaves, J. Hurst, E.A. Jansen, T.W. Johansen, J. de Jong, D. Jouan, J. van der Kooij, E.-M. Kyheroinen, F. Mathews, T.C. Michaelsen, J.D. Møller, G. Pētersons, N. Roche, L. Rodrigues , J. Russ, Q. Smits , S. Swift, E. T. Fjederholt, P. Twisk, B. Vandendriesche & M.J. Schillemans |
| Kwaliteitscontrole: | Marcel Schillemans |
| Productie: | Steunstichting VZZ, in rapport vermeld als de Zoogdiervereniging |
| | Bezoekadres: Toernooiveld 1, 6525 ED Nijmegen |
| | Postadres: Postbus 6531, 6503 GA Nijmegen |
| | Tel.: 024 7410500 |
| | secretariaat@zoogdiervereniging.nl |
| | www.zoogdiervereniging.nl |
| Gegevens opdrachtgever: | Wageningen Marine Research<br>Ankerpark 27<br>1781 AG Den Helder |
| Contactpersoon opdrachtgever | Michaela Scholl |

**De Steunstichting VZZ is onderdeel van de Zoogdiervereniging**


## Dit rapport kan geciteerd worden als:

Limpens, H.J.G.A., S. Lagerveld, I. Ahlén, D. Anxionnat, T. Aughney, H.J. Baagøe, , L. Bach, P. Bach, J.P.C. Boshamer, K. Boughey, T. Le Campion, M. Christensen, J.J.A. Dekker, T. Douma, M.-J. Dubourg-Savage, J. Durinck, M. Elmeros, A.-J. Haarsma, J. Haddow, D. Hargreaves, J. Hurst, E.A. Jansen, T.W. Johansen, J. de Jong, D. Jouan, J. van der Kooij, E.-M. Kyheroinen, F. Mathews T.C. Michaelsen, J.D. Møller, G. Pētersons, N. Roche, L. Rodrigues , J. Russ, Q. Smits , S. Swift, E.T. Fjederholt, P. Twisk, B. Vandendriesche & M.J. Schillemans, 2017. Migrating bats at the southern North Sea - Approach to an estimation of migration populations of bats at southern North Sea . Rapport 2016.031. Zoogdiervereniging (Dutch Mammal Society), Nijmegen/ Wageningen Marine Research .

Contents

## Summary

Bats experience a fatality risk at wind turbines. Since some species migrate not only over land, but also over sea, offshore turbines might pose a threat. To be able to assess the impact of potential added mortality at sea, it is necessary to know or estimate the population size of bats, including the portion of the population crossing the sea. Potentially relevant species are Nathusius' Pipistrelle (*Pipistrellus nathusii*), Common Noctule (*Nyctalus noctula*) and Particoloured Bat (*Vespertilio murinus*).

The current study aims at developing a prototype estimator for migrating populations of bats. This is based on data, or estimates, regarding the size and bandwidth of source populations, population dynamical factors defining such populations, and factors defining migration fluxes. Acknowledging the rareness of such data, a flow model is constructed targeting a preliminary estimate for the southern North Sea (SNS). However, the approach can be adapted for use in other regions/study areas as well.

The model is based on available information and data regarding bat species in the different countries bordering the SNS. This includes countries further off, which might be 'source countries' of bats that eventually might fly on the SNS.

The approach to the estimation of basic data, as well as the flow model, was a cyclical process together with members of a design team from these countries. Together with other contributing colleagues from their region, information and data were brought together. Information on the non-availability of data, or knowledge gaps, are an important part of the result.

The flow model consists of a series of interconnected excel sheets incorporating the basic data for the countries and fluxes. In the current model, parameters used per country are: population size of males, females and juveniles (M, F and J), the percentage of migrating individuals (M, F and J), percentage migrating towards different connected countries in the west/southwest direction, percentage migrating over land/sea, as well as generic factor parameters: basic population dynamical factors such as J/F and satellite males/male.

Currently the model focuses on the Nathusius' Pipistrelle, because this is the species where some information and data are available. Even for this species quantitative basic estimates on source populations were only available for RO Ireland, UK (specifically for England and northern Ireland) and the Netherlands.

The model produces a preliminary estimate for bats crossing the SNS of roughly 40.000 individuals with a bandwidth between 100 and 1.000.000 individuals. The accuracy of this outcome can (and must) be improved through assessment of (more accurate) data and/or estimates per country/region to improve the different factor components per country, to define the now generic factor components as components per country, and to incorporate mortality during migration.

## Reading guide

In chapter 1, introduction, the context of bats over the southern North Sea and aim of the study, targeting at an estimator for source populations and migrating populations, are explained.

Note: To facilitate easy reading for the non-bat-specialist, the content of the chapters is focused on the estimator, where background information is provided in the annexes. This leads to some repetition of text in the Annexes.

Note: some of the literature references will be found in the more elaborate text on specific topics in the annexes.

Chapter 2, method, deals with the process of designing a prototype estimator with concurrence of a team of bat experts in the relevant north west European region. The species to use for the design are selected. The methods for estimating basic input parameters, as well as a flow model for the in and outfluxes of migration connecting the countries in the relevant, area are discussed.

Chapter 3, results, describes the approbation of the design team and other contributors to the approach. The current concrete state of the model is given. The information used for input, and available/non-available data for the different countries is described.

In chapter 4, conclusions and discussion, an analysis of the current state of the estimator is given. Knowledge gaps are identified. The output values in the current state of the model are interpreted.

Chapter 5 lists the knowledge gaps and priority research questions.

# 1. Introduction

The main research question is to estimate migrating populations of bats over the southern North Sea. Also estimating the number of bats of the source population from where the migrating bats originate, is an important research goal.

## 1.1 Context

Different studies in Europe and the USA reveal bat fatalities at wind turbines on land and show the potential of high numbers of fatalities (Brinkmann *et al.* 2011, Voigt *et al.* 2015). Fatalities are occurring from direct collisions with the rotor blades as well as through barotrauma as a result of the low pressure and dynamics in pressure in the air turbulence near the rotor blades (Brinkmann *et al.* 2011, Lehnert *et al.* 2014, Voigt *et al.* 2015). Some bat species are observed at sea at the southern North Sea (SNS), which might reflect migration as well as foraging (Lagerveld *et al.* 2014a, Peterson *et al.* 2014). Although carcasses are not expected to be found at offshore turbines, there is no reason not to expect collisions and/or barotrauma with respect to bats and wind turbines at sea.

Bats are frequently recorded in the study area: the southern North Sea (study area as defined in Leopold *et al.* 2014). Observers of bird migration at the Dutch coast regularly report bats flying in from sea and there have also been offshore observations during ship-based surveys (e.g. Ahlén *et al.* 2009, Hobbs 2014, Lagerveld *et al.* 2014b). In addition, bats have been found on oil and gas platforms, ships and remote islands (Ahlén *et al.* 2007, Walter *et al.* 2007, Boshamer & Bekker 2008, Petersen *et al.* 2014, Rydell *et al.* 2014). Studies with passive acoustic recorders in 2012, 2013, 2014 and 2015 off the Dutch coast revealed that bats are recorded at every location where a bat detector was installed offshore (Jonge Poerink *et al.* 2013, Lagerveld *et al.* 2014a, 2015 & 2016).

The most common species in the study area is Nathusius' Pipistrelle (*Pipistrellus nathusii)*. Common Noctule (*Nyctalus noctula)* and Particoloured Bat (*Vespertilio murinus)* also probably occur regularly at the southern North Sea. Other species like Common Pipistrelle (*Pipistrellus pipistrellus)*, Northern Bat (*Eptesicus nilssonii)*, Serotine Bat (*Eptesicus serotinus)* and Leisler's Bat (*Nyctalus leisleri)* have all been observed at the southern North Sea, but are likely to be more occasional visitors or vagrants (Hüppop & Hill 2016, Lagerveld *et al.* 2014a, Leopold *et al.* 2014).

Nathusius' Pipistrelle, Common Noctule and Particoloured Bat are migratory species which may cover large distances during migration (e.g. Hutterer *et al.* 2005, Roer 1995). Most offshore bat activity occurs during autumn from late

August until early October and to a lesser extent from late March until late May. Records in June and July are very scarce. The observed pattern of occurrence in combination with the species composition strongly suggests that offshore bat activity is caused by migrants (Hüppop & Hill 2016, Leopold *et al.* 2014).

Most bat activity occurs during nights with low wind speeds, high atmospheric pressure and no rain. Therefore, it seems unlikely that bat activity at sea is predominantly caused by individuals blown offshore (Lagerveld *et al.* 2014b). This corresponds with the findings of Ahlén *et al.* (2007, 2009) who observed that migrating bats aggregate at coastal locations and wait for favourable conditions to cross over the Baltic Sea. However, Hüppop & Hill (2016) show that migration occurs both with tailwind and headwind.

Several ringing recoveries of Nathusius' Pipistrelles have shown that they are able to successfully cross the North Sea[1]. In addition these recoveries (n=4) show that the migration direction of these individuals is roughly from east northeast to west southwest.

Leopold *et al.* 2014 concluded that, in the light of the increasing area and numbers of wind turbines on the southern North Sea, negative effects on bat populations, at least for the Nathusius' Pipistrelle (*Pipistrellus nathusii*), and possibly also for the Common Noctule (*Nyctalus noctula*) and the Particoloured Bat (*Vespertilio murinus*) cannot be excluded.

## 1.2 Aim of the study

The ultimate aim of this study is to be able, in the future, to assess the number of bats crossing the SNS, in comparison to the number of bats residing in the various countries.

To be able to do so, population estimates (paragraph 2.1 and 2.4) for the different regions, as well as a practically applicable numerical model for the migration flux (paragraph 2.1 and 2.5) are needed. This study aims at developing a prototype estimator, regarding national/regional estimates and the migration flux and assessing the availability of the necessary data. The process of developing such a prototype estimator will highlight knowledge gaps. In principle, the approach targets all bat species that regularly occur on the North Sea. Availability of data will determine which species practically can be used for the first steps towards estimating migrating populations of bats.

[1] see e.g. (http://www.bats.org.uk/pages/national_nathusius_pipistrelle_project.html).

## 2. Method

To be able to estimate the number of individuals of a bat species that might be migrating across the SNS, information is needed regarding the factors defining the population size and their movements.

We worked with an approach where we try to A] model the migration flux, based on B] available data. The available data consist of either quantitative or estimated information of the parameters defining the population dynamics, as well as the migration, for the different regions in the relevant geographical population/migration area for the species (Figure 1).

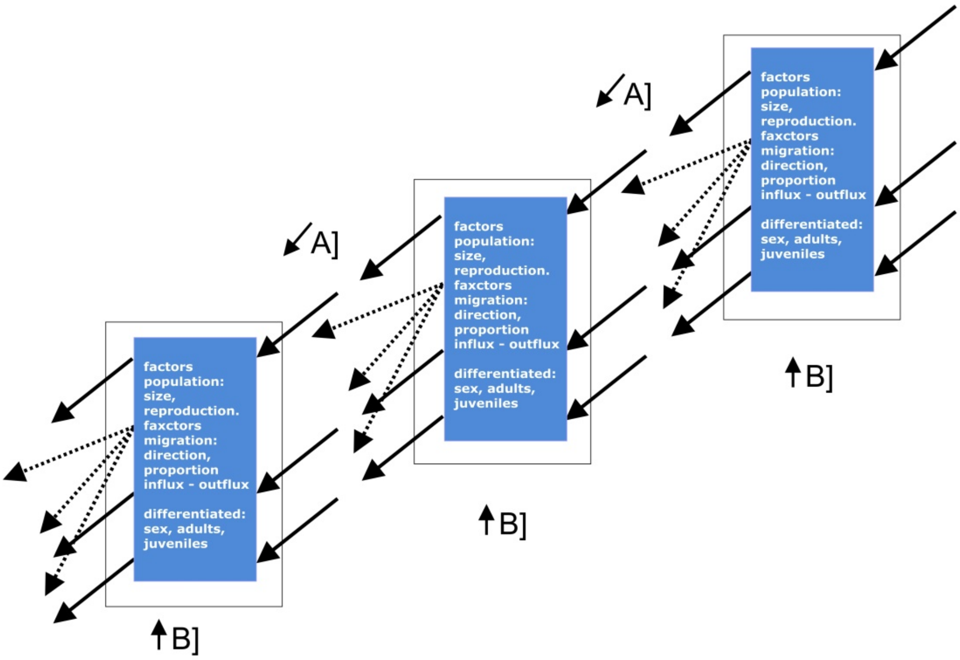



Figure 1: principle of combination of B] regional basic data as input for A] the flow model

Combined, the components of the basic regional data and the flow model build the basis for the assessment of the migration pattern of the relevant species in Europe. All different components of the model and estimations will have their own specific and probably large uncertainty intervals.

Leading questions[2] for the structure of model are listed below.

- What are the source populations of bats potentially migrating over the SNS?
- What are the population sizes of the source populations? What quantitative information is available on numbers of different roost types (maternity, summer, mating and hibernation roosts), numbers using these (networks) of roosts? How is this reflected in numbers of males, females and offspring?
- What are the approximate directions, areas of migration and landscapes used for migration of the source populations?
- What is the number of animals, or parts of the source populations that migrate through these areas and landscapes? What is the number of individuals (males, females, offspring) that do not take part in migration?
- Is there a more or less random migration flow across (the southern North) Sea, or is there an – observable - differentiation between following the coast lines and migrating over sea? What might be the size of sub-populations migrating across the sea and those following the coast line?
- What might be the overall size of the population migrating over the SNS?

The construction of a flow model and discussions regarding the input and outcome of several test runs are an effective way of producing first estimates as well as of detecting knowledge gaps. This is why regional bat specialists were invited to take part in the model development. They were asked to provide feedback on the structure of the flow model and as a source of information, to help estimate and/or give their expert judgement regarding chosen values.

Both the A] flow model and B] estimates for basic regional input should be usable in an iterative approach regarding the estimates. Chosen or estimated values of one parameter influence the outcome of others and provide feedback that can be validated. This process starts with expert judgement and in the end makes clear what research is needed for further ground truthing.

In working with this approach it is logical to think from the view point of the flow model, which needs to be based on basic regional data. In the development of this integrated approach, however, the development of the approach to B] assessing basic regional information, preceded the development and testing of A] the flow model. Therefore in our reporting we start with B] (paragraph 2.4) followed by A] (paragraph 2.5).

[2] In this study we are not necessarily providing answers to all of these questions, or answering them completely.

## 3. Design process

The design process is summarized in Table 1.

A number of European bat researchers was contacted and invited to take part in the team for the first design and development of the estimator B] for the basic regional data, and later on A] the flow model. They were also asked to bring together available data and information via their network in their regions. Together we have been designing and developing a prototype estimator.

In a first loop, a draft approach for the B] estimation of the basic regional data and a first sketch of the flow model were developed. They were presented in the form of a PowerPoint (e.g. illustration of approach geographically) and Questionnaire (Excel-table for collecting information (see Annex I). These first sketches were discussed with the members of the design team. Comments and remarks were processed.

The approach to the B] estimation of the basic regional data and the questionnaire was then distributed, directly and/or via the members of the design team, to an extended number of bat experts[3] in their region(s) and countries.

The first round of feedback and the first basic information from the participants were then used to specify the design of A] the flow model approach.

Next, the basic data and information on non-availability of data, received from the participants, were used as first input for the flow model. The flow model – in the form of a series of interrelated excel sheets – was then used to collect new feedback on the flow model approach and on the chosen estimates.

Note: designing and building of the model, as well as gathering input, involved repeated feedback (Table 1). The main ingredients of this cyclical process, more specifically of the design process, e.g. relevant species, participants, premises for the model, selection of countries/regions to take into the model etc., are presented in the following paragraphs of the method description.

[3] The data and information brought together will be made available to all participants. All contributors are co-authors of this technical report.

Table 1: Time line of the design process

| | | |
|---|---|---|
| **2016** | | |
| 05 | | Recruitment of participants design team |
| 05 / 06 | | Design of B] estimator approach for basic regional data + first sketch of flow model |
| | | Development of B] questionnaire for collation of basic reginal data |
| | | ↓ ↑ |
| | | Collecting + processing feedback of members of design team |
| 06 / 07 | | Recruitment of extended number of regional experts |
| | → | Distributing information on B] approach to basic regional data to all participants |
| | | ↓ ↓ |
| 08 / 11 | | Collecting input and data from all experts, including information on (non)availability of basic data |
| | | ↓ ↓ |
| 10 / 12 | | Design of A] flow model (based on already available/non-available information) |
| 11 / 12 | | Test runs of flow model with |
| **2016/2017** | | |
| 12 / 01 | → | Distributing information on A] approach to flow model to design team |
| | | ↓ ↑ |
| | | Collecting + processing feedback of members of design team |
| | → | Distributing information on A] approach to flow model to all participants |
| **2017** | | |
| | | ↓ ↓ |
| 01 | | Collecting input from all participants regarding general and country/region specific estimates which are used as input to the flow model. |
| 2017 | | ↓ ↓ |
| 01 | | Draft report on constructed flow model and outcome. |

## 3.1 Participants

Using our network of European bat scientists and conservationists from BatLife Europe, the Eurobats Advisory Committee and the regular European Bat Research Symposia we established the following expert team of participants in the process.

Expert colleagues participating in the first loop of feedback for designing and gathering of data:

Hans Baagøe, Lothar Bach, Katherine Boughey, Marie-Jo Dubourg-Savage, Eric Jansen, Jeroen van der Kooij, Sander Lagerveld, Herman Limpens, Tore Michaelsen, Gunārs Pētersons, Niamh Roche, Luisa Rodrigues, Jon Russ, Marcel Schillemans, Esben Terp Fjederholt, Bob Vandendriessche;

Expert colleagues participating in the second loop of feedback on flow model and basic data:

Ingemar Ahlén, Tina Aughney, Diane Anxionnat, Petra Bach, Jan Boshamer, Thomas Le Campion, Morten Christensen, Julie Dahl Møller, Jasja Dekker, Theo Douma, Jan Durinck, Morten Elmeros, A-J Haarsma, John Haddow, Daniel Hargreaves, Johanna Hurst, Thomas Johansen, Johnny de Jong, Dorothee Jouan, Eeva-Maria Kyheröinen, Fiona Mathews, Susan Swift, Peter Twisk;

## 3.2 Choice of relevant species for the estimator

Based on the assessment of relevant species for the estimator, presented in Annex II, three species might be relevant for the development and use of the flow model estimator A]. These are the Nathusius' Pipistrelle (*Pipistrellus nathusii*), the Common Noctule (*Nyctalus noctula*) and the Particoloured Bat (*Vespertilio murinus*).

Technically the approach of the flow model is applicable to all three species. However, the available basic information B] in the different countries is rather poor. This is the case for the most common of the species, the Nathusius' Pipistrelle, and even more so for the other species.

Therefore, in this study the flow model is developed using data on the Nathusius' Pipistrelle only. We expect that the structure of the model and knowledge gaps deduced from working with the Nathusius' Pipistrelle, will be representative of the situation of other species.

## 3.3 B] Basic regional data and estimates

Input for the basic regional information, data and estimates were gathered through a detailed questionnaire (see annex II, III and questionnaire) and literature research.

The approach to the estimation of the size of populations and migration movements tries to use different and independently assessable components. These are components for which data and information might either be currently available, or of which the numbers might currently be reliably estimated.

A basic approach to the estimation of the size of a source population, e.g. a maternity population in one of the Baltic States, is described in Table 2.

In the same way, the size of a target population, e.g. the population of advertising males, (clusters of) mating roosts, in the Netherlands, might be estimated as described in Table 3.

The same approach can be used for summer roosts and hibernation sites. The validity of the outcome is of course dependent on the available data and the sub-estimates that we can deduct from them.

Table 2: Example of the estimation of a source population. The numbers in the table are just examples for the calculation.

| | | | |
|---|---|---|---|
| | **Approach to quantification of source population for a specific region** | | |
| | | | |
| | Maternity colonies (network of roosts) / summer roosts | | |
| | | | |
| A | estimate # known maternity colonies: | 15 - **35** - 60 | roughly 1/3 |
| | | | |
| B | estimate # unknown maternity colonies: | 30 - **70** - 120 | roughly 2/3 |
| | | | |
| C | estimate average # individuals/colony: | 100 - **150** - 200 | |
| | | | |
| | preferable foraging grounds for the species: Wetlands, shores, broadleaved forest,…. | | |
| | | | |
| D | estimate average area ([foraging] home range) one colony? | 8 – **12** – 16 km$^2$ | |
| | | | |
| E | estimate available area qualified habitat (roosts and foraging)? | 500 - **1500** -2500 | |
| | | | |
| | (A+B)*C → source population : | 4500 – **16.000** – 36.000 | |
| | | | |
| | **Cross checks** | | |
| | | B*C | E/D*C |
| | Is B*C roughly similar to E/D*C **?** | 3000 – **10.500** – 24.000 | 6.250 – **18.750** – 31.250 |
| | | | |
| | If the numbers chosen for this example would be true numbers/sub-estimates, this comparison indicates the need for more information and adjustment of the estimates. | | |
| | | | |
| | Is (A+B)*D roughly similar to E **?** | (A+B)*D | E |
| | | 360 – **1.260** – 2.880 | 500 - **1500** -2500 |
| | If the numbers chosen for this example would be true numbers/sub-estimates, this comparison indicates a reasonable similarity. | | |
| | | | |

Table 3: Example of the estimation of a target population. The numbers in the table are just examples for the calculation.

| | | | |
|---|---|---|---|
| | **Approach to quantification of target population for a specific region** | | |
| | | | |
| A | estimate # investigated clusters of mating roosts: | 30 - **50** - 70 | roughly ½ ? |
| | | | |
| B | estimate total # unknown clusters of mating roosts/: | 30 - **50** - 70 | roughly ½ ? |
| | | | |
| C | estimate average # individuals/known mating roosts/clusters of: | 20 - **40** - 60 | males |
| | | | |
| | (A+B)*C = # males | 1,200 – **4.000** – 8.400 | - |
| | | | |
| D | Estimate # of visiting females | 3.600 – **12.000** – 25.200 | 3 f/m? |
| | Assumption: 1 female visits 2 male sites in NL region (turnover): | 1.800 – **6.000** - 12.600 | |
| | | | |
| | preferable foraging grounds for the species: Wetlands, shores, broadleaved forest,…. | | |
| | | | |
| E | estimate average area ([foraging] home range) one mating roost? | 1 - **2** - 4 $km^2$ | |
| | | | |
| F | estimate available area qualified habitat (roosts and foraging)? | 200 - **500** - 800 $km^2$ | |
| | | | |
| | **Cross checks** | | |
| | | (A+B)*C | F/E*C |
| | Is (A+B)*C roughly similar to F/E*C ? | 1,200 – **4.000** – 8.400 | 10 – **1.000** – 12.000 |
| | If the numbers chosen for this example would be true numbers/sub-estimates, this comparison indicates the need for more information and adjustment of the estimates. | | |
| | | | |

Via the questionnaire, the input of expert team and contributors, personal comments of participants and literature, basic relevant information on ecological and population dynamics parameters was brought together. The questionnaires for the different regions assessed the (availability of) data and possible estimates for the different parameters for this specific region, as well as knowledge gaps and data deficiency.

For the basic regional data information was sought on the parameters as listed in Table 4.

Table 4: Components for estimate used in questionnaire

| | |
|---|---|
| Population | (estimated) regional population size; |
| Migrating part of .. | (estimated) size of migrating part of this population; |
| Migration direction | (expert judgement on) direction(s) of the migration; |
| Direction/ part of .. | plus part of population(s) using this/these direction(s) |
| Migration area | (expert judgement on) area of migration zone(s); |
| Number(s) of roost | (estimated) number of known and unknown maternity colonies/groups in the area; likewise for summer colonies/roosts, (clusters of) mating roosts and hibernacula; |
| Number(s) of individuals / roost | (estimated) number of individuals in maternity colonies/groups in the area; likewise for summer colonies/roosts, (clusters of) mating roosts and hibernacula; |
| Home range / roost | (estimated) size of the area used by one maternity colony; likewise for summer colonies/roosts, (clusters of) mating roosts and hibernacula; |
| Migration landscape | (expert judgment) landscape types used for migration; |
| Migration over sea | (expert judgment) existence of migration over sea; along coastline; |
| Front - funnelling | (expert judgment) existence of funnelled migration and/or migration over a broader front; |

The information used consists of estimated values (basic estimate[s] + lower and upper values) for specific source or target populations in the different (regions of) countries around the southern North Sea, such as 'the number of maternity roosts in the source population in Lithuania', 'the % of migrating males or females', or 'the numbers of (clusters of) mating roosts in the Netherlands, a target area'.

## 3.4 A] The flow model approach

The basic idea of the migration flow model is to assess data of the population flowing into and out of a specific country or geographical area, and linking this to the neighbouring countries or area (the size of the movement can be called flow or flux). For this study, this is captured in a series of interrelated excel-tables which are available with this document (Figure 2).

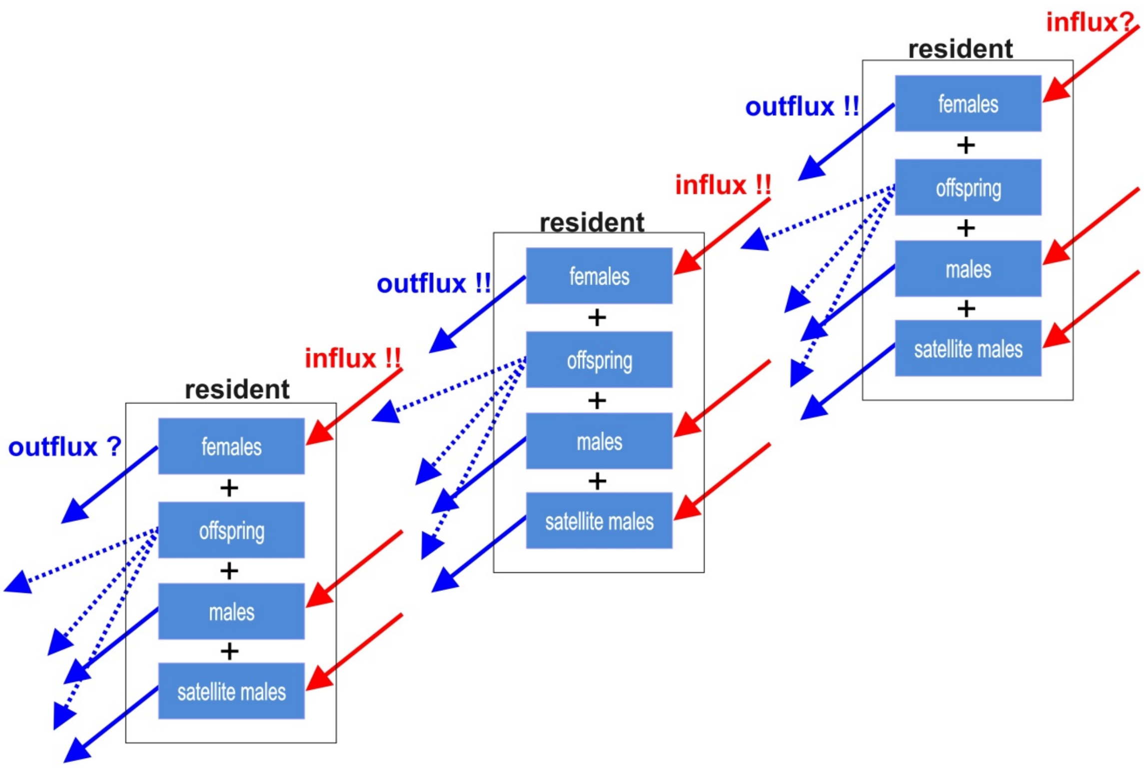
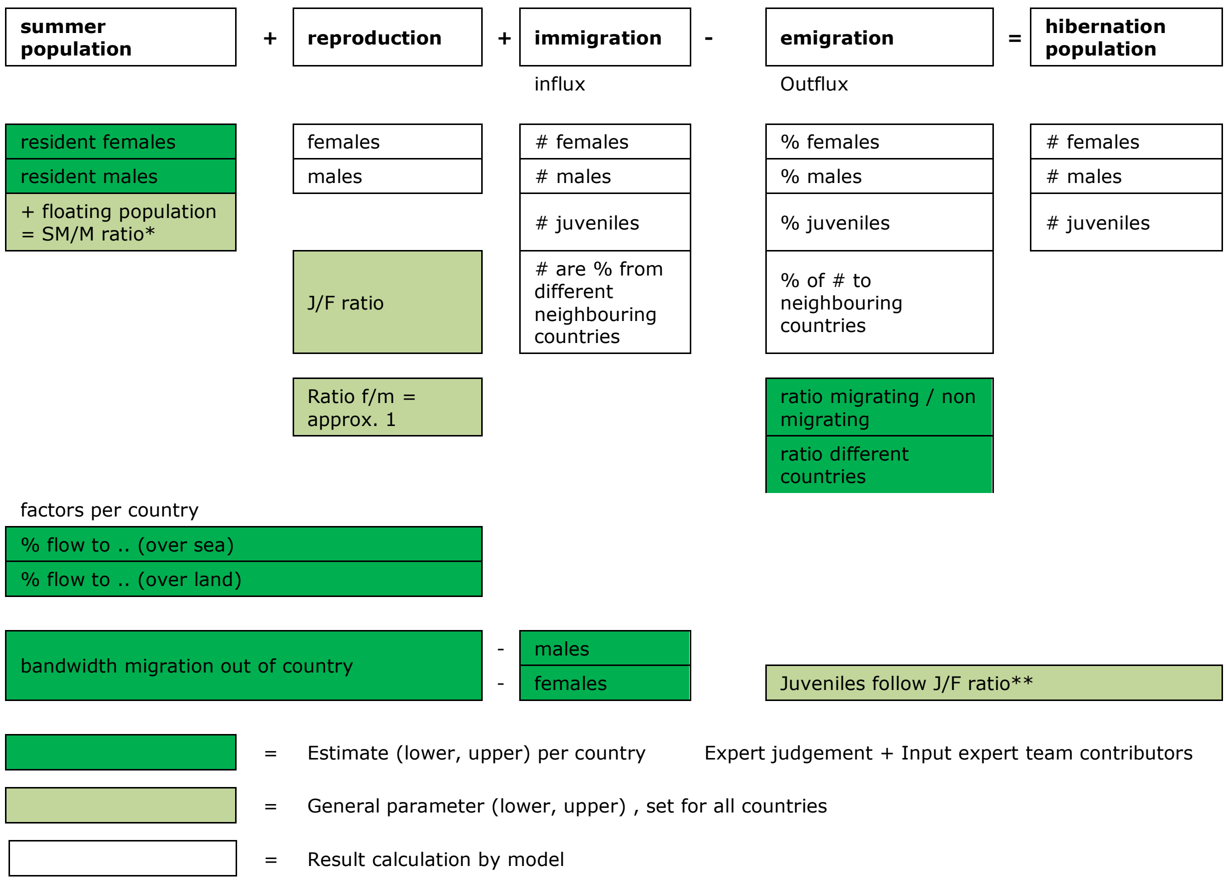



Figure 2: schematic image of the flow model: [the population present in the 'summer season'], plus [influx], minus [outflux], for males, females and offspring (only outflux), equals the hibernating population.

For the flow model we work with the principle that the summer population, plus immigration, minus emigration, for males, females and offspring, equals the hibernating population (see Table 5).

Table 5: components of the flow model A] for the migration population of *Pipistrellus nathusii* relevant for the estimation of the population migrating on the southern North Sea.




** SM/M ratio = satellite males/male ratio
*J/F ratio = juvenile/female ratio

Working with this flow model A] needs a series of premises (for more detail see annex IV), which of course will lead to a simplification of reality. Numbers in and numbers out are estimates, where possible based on the basic regional data B] from the questionnaires, and will come with an uncertainty interval. The premises used are based on literature and the feedback from the expert team and contributors. For more detail see annexes IV (premises) and V (summary complex geographic interconnection between distribution, mating/reproduction and migration of the Nathusius' Pipistrelle).

Premises[4] regarding the migration flow model are:

a) Our focus is on the Nathusius' Pipistrelle.

b) Our focus is on information related to the autumn migration period.

c) We work with a main migration direction from east/northeast to west/southwest for the autumn migration. However a smaller part of the population may have more west or more southwest directions. Directions south, following western coast lines and river valleys, and even south/southeast, along the east coast of Denmark are also (input Hans J. Baagøe & Terp Fjederholt) observed. Drift cannot be excluded (Hüppop & Hill 2016; extended references in Annex IV).

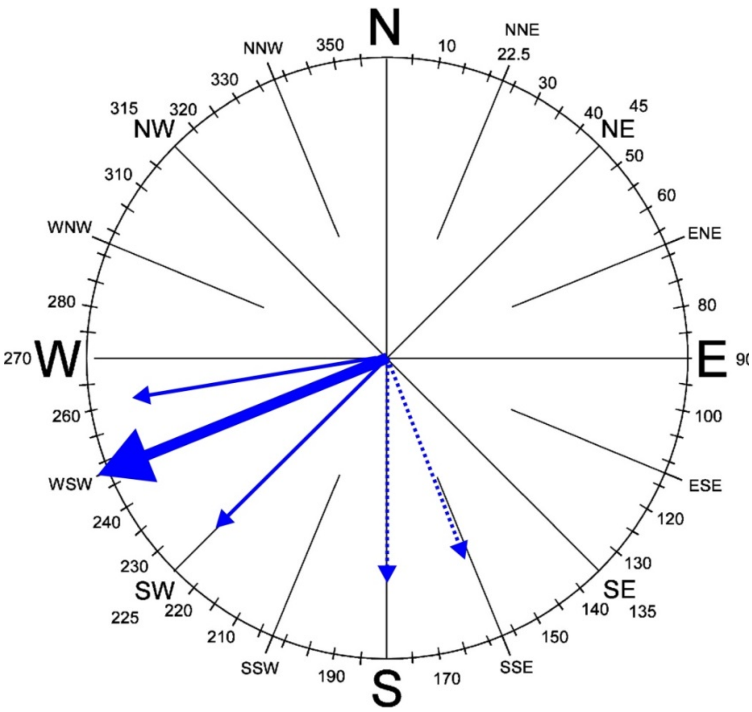



Figure 3: Main migration direction, and other observed directions (see text).

d) We work from the concept of a broader migration front rather than narrow corridors. At the same time the existence of funnelling along the coast and along river valleys is a fact. This may also lead to a more north to south migration direction on parts of their route (questionnaires and literature: Ahlén 1997, Ahlén *et al.* 2007, 2009; Brinkmann *et al.* 2011; Lagerveld *et al.* 2014a).

[4] The premises for the model are a first result of the design process with the expert team members: input from expert team and literature. For all premise(s): premise = interpretation of the available knowledge in a way that allows for calculation in the estimation.

e) Larger areas of water will be crossed (see e.g. Ahlén 1997, Ahlén *et al.* 2007, 2009), where there is no other (logical) choice, such as 1) at the south points of isles, 2) at sites where the coastline turns land inward (direction SE and E), and 3) in situations where the coastline for longer distances deviates from the general migration direction (e.g. longer stretches of north south coastlines).

f) Based on the selection of relevant species and the developed approach, source and target areas of bats migrating above and/or along the coast of the southern North Sea are identified (see also: (www.grida.no[6], Limpens & Schulte 2000). We incorporated Norway, UK (Scotland, Northern-Ireland, England and Wales), the Republic of Ireland, Finland, Sweden, Estonia, Latvia, Lithuania, north western part of Poland, Denmark, the northern part of Germany, the Netherlands and Belgium in the flow model.

   Migrating bats from these countries might be arriving at the southern North Sea. Populations migrating from/though Norway would end up in the northern North Sea outside our study area. Norway is included, however, because their outflux may be an influx to Scotland and Northern Ireland. Migrating bats from more southern or south eastern countries in Europe would end up more to the south of the current study area.

g) Finland is 'purely source country' in the sense that there is no influx of migrating bats from neighbouring countries. Norway may or may not have an influx from Sweden, but an outflux from Norway does not add to a flux over the current study area. The western territory of Russia, bordering to the Baltic States and Belarus, is only incorporated as a source area. Other countries incorporated in the flow model will have an influx and outflux of migrating bats.

[6] http://www.grida.no/graphicslib/detail/nathusius-pipistrelle-distribution-and-migration_18cb

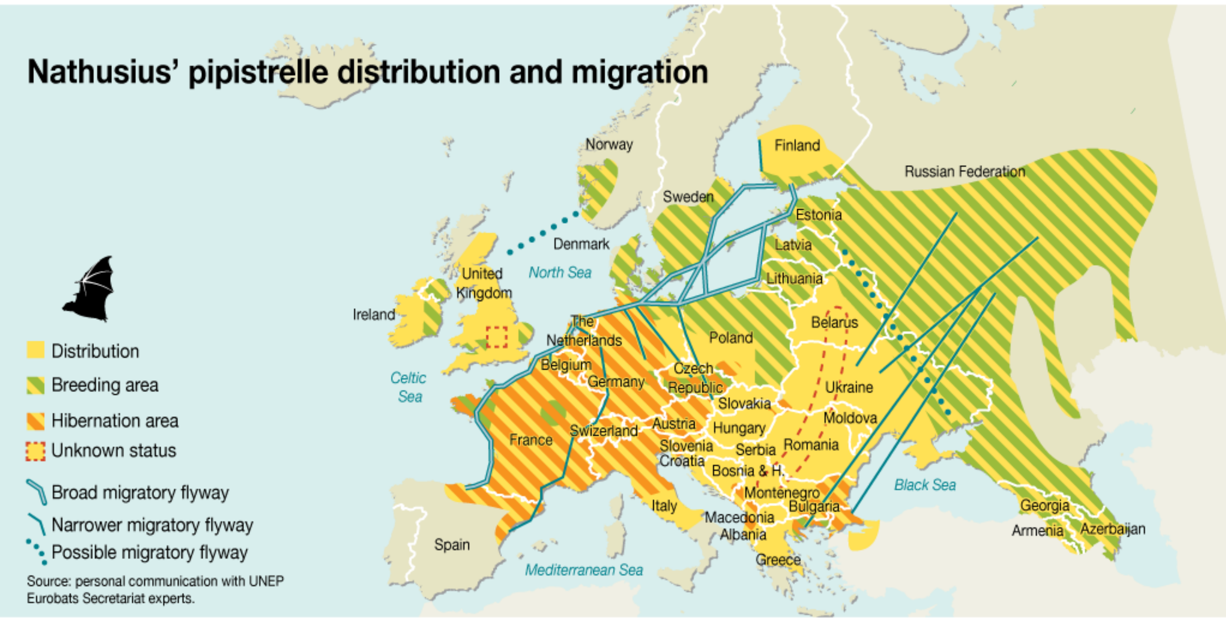



Figure 4: Nathusius' Pipistrelle distribution and migration (From collection: Living Planet: Connected Planet, Rapid Response Assessment, Riccardo Pravettoni, UNEP/GRID-Arendal, 2011).

Ad Figure 4: Note: We use this illustration because it gives a quit good overview, but since 2011 new data is available. Please note that no maternity groups are ever discovered in Norway, nor were any of the captured Nathusius' Pipistrelles females (J. v.d. Kooij, pers. com.). A possible flux from Sweden to Norway (J. v.d. Kooij, pers. com.) is not depicted in this illustration. Also all areas without breeding, in the sense of occurrence of maternity sites, are qualified as hibernation area. The fact is that many sites with (clusters of) mating roosts are found in both the maternity and hibernation area.

h) We work on the premise that the majority of the animals from the northern (Scandinavia) and north-eastern European maternity regions (Baltic States, western Poland and western Russia) will hibernate in western Europe, in the present case in middle-western Europe.

i) We work on the premise that the number of females born is equal to the number of males, and that there is an equal survival for both sexes.

j) The ratio between territorial males and satellite males is unknown. It is unclear whether there would be different ratios for different zones in the migration direction. We work with a large uncertainty interval: lower-**central**-upper: 0.2–**2**–5, and we also calculate with different settings: 3–**4**–5, 2–**3**–4, 1-**2-**3 and 0.2-**1.2**-2.2 satellite males per territorial male (pers. com. Peter Lina). Working with a range of settings provides insight into the effect of this component on the outcome.

k) We work on the premise that yearling males for the larger part will take part in migration, as does the larger part of yearling and adult females. In comparison adult territorial males will, for a larger part, stay behind (e.g.

Boshamer & Bekker 2009, Lina pers. comm.). This is incorporated in the bandwidth for migration of the separate groups per country in the model. We work with the assumption that at least a part of the non-resident male population, that is the population that does not occupy their own mating roost/territory, also migrates.

l) We work on the premises (e.g. Lina pers. comm. Limpens & Schulte 2000, Petersons 1990, 2004, Petersons & Lapina 1990) that:
- in all geographic regions, more females will take part in migration than males;
- the more west/southwest in Europe we get, the less males take part in migration, and thus the more males stay behind (establishing a territory or only hibernating)
- in the autumn, in the northeast of Europe most females will migrate, while more to the southwest a larger part will stay behind (hibernate).

This effect is accounted for by estimating the bandwidth of which part will migrate out of the specific country (Table 6).

Table 6: Example table: Estimated bandwidth of the part of the population that will migrate, per country. Values presented in this table are the values used in the first draft in the excel sheets for the flow model. Note: Current values with input of design team and other contributors are in the excel sheets for the flow model.

| bandwidth migration out of | male low | male | male up | | fem low | fem | fem up |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Finland | 0,250 | **0,750** | 1,000 | | 0,300 | **0,900** | 1,000 |
| Estonia | 0,125 | **0,600** | 0,800 | | 0,300 | **0,900** | 1,000 |
| Sweden | 0,250 | **0,750** | 1,000 | | 0,300 | **0,900** | 1,000 |
| Lithuania | 0,125 | **0,500** | 0,750 | | 0,300 | **0,800** | 0,950 |
| Denmark | 0,100 | **0,400** | 0,600 | | 0,200 | **0,800** | 1,000 |
| Poland / north west | 0,100 | **0,400** | 0,600 | | 0,200 | **0,800** | 1,000 |
| Belarus | 0,125 | **0,600** | 0,800 | | 0,300 | **0,750** | 0,850 |
| Latvia | 0,125 | **0,600** | 0,800 | | 0,300 | **0,700** | 0,800 |
| Germany / north | 0,050 | **0,250** | 0,500 | | 0,250 | **0,750** | 1,000 |
| Netherlands | 0,050 | **0,250** | 0,500 | | 0,250 | **0,750** | 1,000 |
| Belgium | 0,050 | **0,250** | 0,500 | | 0,250 | **0,750** | 1,000 |
| Norway | 0,25 | **0,75** | 1 | | 0,3 | **0,9** | 1 |
| UK Scotland | 0,25 | **0,75** | 1 | | 0,3 | **0,9** | 1 |
| UK Northern Ireland | 0,1 | **0,5** | 0,9 | | 0,3 | **0,9** | 1 |
| UK England/Wales | 0,25 | **0,75** | 1 | | 0,3 | **0,9** | 1 |
| Republic of Ireland | 0 | **0** | 0 | | 0 | **0** | 0 |

m) There are very few data on the fecundity of bats. Available data show J/F ratios of around 0.6 to 0.8 (e.g. O'Shea *et al.* 2011, Schaub *et al.* 2007). We work on the premise that every adult female that is part of the western European migrating population will on average have 0,7 offspring per year. We calculated with the following variability: (min)-(central)-(max): 0.6-**0.7**-0.8, 0.5-**0.6**–0.7 and 0.4–**0.5**–0.6 juveniles per female. Working with a range of settings provides insight into the effect of this component on the outcome.

### Gathering of data and input for the A] migration flow model

Estimates and information for the flow model (figure 2) was first sought after through input in the questionnaires / completed excel sheets for (B] available regional data. In the next step, renewed input was gathered through distribution of the excel file with the A] migration flow model, comprising the interconnected excel tabs per country. Here the different members of the design team were asked to comment on the chosen preliminary values for the components (see excel sheet flow model).

**NETHERLANDS**

| | |
|---|---|
| **colour code** (bright green) | **these are estimates where we want the expert-team/country expert to give comment;** |
| | **NOTE: DO NOT ALTER THE VALUE IN THE TABLE, BUT GIVE YOU COMMENT/YOUR ESTIMATE SEPARATELY !!** |
| | **EITHER BY COPYING THIS TAB AND FILL IN THE BRIGHT GREEN CELLS, OR BY USING THE REPLY TAB.** |
| | **NOTE: please give us sources: expert judgement - or - literature** |
| **colour code** (light green) | **these values are based on other tabs: general parameters, values defined in tab for country north and northeast of your own, values on %flow (below), and bandwidth male and female migrat** |
| | **NOTE: do not alter the value in the table !!!** |

| *Summer population in* | *Ad male* | *Sources* | *Ad female* | *Sources* | *Juv* | *Sources* | *Ad male m* | *Source* | *Ad female* | *Sources* | *Juv min* | *Sources* | *Ad male m* | *Sources* | *Ad female* | *Sources* | *Juv max* | *Sources* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maternity colonies | | | 100 | | 70 | | | | 0 | | 0 | | | | 1.000 | | 800 | |
| Male roosts (late summer) | 18.450 | | | | | | 3.180 | | | | | | 56.700 | | | | | |
| Satellite adult males | 73.800 | | | | | | 9.540 | | | | | | 283.500 | | | | | |
| Total | 92.250 | | 100 | | 70 | | 12.720 | | 0 | | 0 | | 340.200 | | 1.000 | | 800 | |

| *Migration from* | *Ad male* | *Sources* | *Ad female* | *Sources* | *Juv* | *Sources* | *Ad male m* | *Source* | *Ad female* | *Sources* | *Juv min* | *Sources* | *Ad male m* | *Sources* | *Ad female* | *Sources* | *Juv max* | *Sources* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Denmark to Netherlands (over sea) | 96 | | 472 | | 330 | | 1 | | 3 | | 2 | | 3.638 | | 7.114 | | 5.691 | |
| Germany to Netherlands | 20.744 | | 43.637 | | 30.546 | | 753 | | 204 | | 122 | | 266.823 | | 874.712 | | 699.770 | |
| Total | 20.840 | | 44.109 | | 30.876 | | 754 | | 207 | | 124 | | 270.460 | | 881.826 | | 705.461 | |

| *Migration to* | *Ad male* | *Sources* | *Ad female* | *Sources* | *Juv* | *Sources* | *Ad male m* | *Source* | *Ad female* | *Sources* | *Juv min* | *Sources* | *Ad male m* | *Sources* | *Ad female* | *Sources* | *Juv max* | *Sources* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Netherlands to UK (over sea)** | **7.068** | | **8.289** | | **5.802** | | **168** | | **13** | | **8** | | **76.333** | | **220.707** | | **176.565** | |
| Netherlands to Belgium | 21.204 | | 24.868 | | 17.407 | | 505 | | 39 | | 23 | | 228.998 | | 662.120 | | 529.696 | |
| Total | 28.273 | | 33.157 | | 23.210 | | 674 | | 52 | | 31 | | 305.330 | | 882.826 | | 706.261 | |
| | | | | | | | | | | | | | | | | | | |
| | balance male | | balance female | | balance juveniles | | balance male min | | | | balance juv min | | balance male max | | balance fem max | | balance juv max | |
| *Winter population in* | *Ad male* | *Sources* | *Ad female* | *Sources* | *Juv* | *Sources* | *Ad male m* | *Source* | *Ad female* | *Sources* | *Juv min* | *Sources* | *Ad male m* | *Sources* | *Ad female* | *Sources* | *Juv max* | *Sources* |
| Winter roosts | 84.818 | | 11.052 | | 7.737 | | 12.800 | | 155 | | 93 | | 305.330 | | 0 | | 0 | |

**note: '0' mean that all individuals would migrate out of the country; maximum migration would lead to a low value or a zero for the hibernating population**

| balance check | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| **Netherlands to UK (over sea)** | 0,250 |
| Netherlands to Belgium | 0,750 |

total = 1

| | | | min | | max |
|---|---|---|---|---|---|
| bandwidth migration Netherlands | males | | 0,050 | **0,250** | 0,500 |
| | females | | 0,250 | **0,750** | 1,000 |

max = equal or smaller 1
max = equal or smaller 1

**note: these values, %flow / outflux and bandwidth, are values where the regional/country expert should give feed back**
**however, when you have data/expert judgment regarding your influx (= outflux country north/northeast) please give your input**

Figure 5: example illustrating the tables used to collect data for the flow model.

# 4. Results: Prototype estimator of populations of migrating bats

## 4.1 Feedback basic regional information and data:

All respondents currently involved in the project agreed on the approach for regional/national estimates, but not everybody had the data or information to provide estimates. Input was given for such data as was available (see Annex III summary feedback basic regional information and data).

Relatively elaborate data and estimates, reported via the questionnaire, were received from the UK, differentiated for Northern Ireland, Scotland, Wales and England, and for the Republic of Ireland and the Netherlands. This is 6 out of 16 units (UK is divided in the 4 countries).

Limited data, and data for smaller regions/sites within countries were received for Germany, Norway, Sweden, Denmark, Finland, Latvia and Belgium. These respondents were not able to present estimates (7/16). Data for Poland, Estonia and Lithuania are currently not available (3/16).
For the Netherlands also data and input for smaller regions/sites within the country were received. For France and Portugal, which are both not within the current range of the model, no estimates could be given. For France data and input for smaller regions/sites within north-western French Départements were shared.

## 4.2 Feedback information and data on flow model

The general opinion of the members of the expert team and the other regional contributors is a consent to the approach of the flow model (see Annex VI: summary feedback on flow model).

More specifically, the respondents for Norway, the UK, the RO Ireland, Latvia, Denmark / northern Germany, Belgium and the Netherlands consented to the (prototype) approach. This is 13 out of 16 units currently in the flow model. Respondents for Finland and Sweden refrained from comment (2/16). Respondents for France and Portugal, not within the current range of the model, respectively refrained from comment and consented. Currently there is no input for Estonia, Belarus, Lithuania and north-western Poland (4/16).

Feedback in the sense of information or comments on input and output of the model was received from Latvia, Denmark, Norway, northern Germany, the Netherlands, Belgium, the UK and the RO Ireland (11/16 ). More quantitative input, in the sense of suggestions for alterations to the used estimates in the flow model were received for northern Germany, the Netherlands, Belgium, the UK and the RO Ireland (8/16).

Although there is a consent to the approach, many of the contributors hesitate to give estimated values for those factors in the excel sheet (see e.g. table 7) where their regional expert input is needed (see Annex IV). This is due to the lack of basic regional data and differences among countries regarding the availability of systematic surveys of occurrences and distribution of bats. Also a lack of experience with expert judging of possible occurrences of bats in landscapes will have played a role. The values used in the flow model are predominantly expert judgement estimates carried out by Herman Limpens. These were based on such input as was available, and adapted where contributors were able to react for their region on the original value in the model (also see accompanying excel sheet, annexes III and VI).

Table 7: overview estimated summer population per country = source population(s) for migration. M= males, MS= Male satellites, F= Females, J= Juveniles

| | central | | | lower | | | upper | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***Male + sat*** | ***fem*** | ***juv*** | ***male*** | ***fem*** | ***Juv*** | ***male*** | ***fem*** | ***Juv*** |
| **Finland** | 1.500 | 5.000 | 3.000 | 150 | 50 | 20 | 30.000 | 50.000 | 40.000 |
| **Estonia** | 900 | 1.800 | 1.800 | 36 | 300 | 120 | 18.000 | 30.000 | 24.000 |
| **Belarus** | 3.000 | 10.000 | 6.000 | 120 | 1.000 | 400 | 6.000 | 100.000 | 80.000 |
| **Latvia** | 1.500 | 5.000 | 3.000 | 60 | 500 | 200 | 30.000 | 50.000 | 40.000 |
| **Lithuania** | 1.500 | 3.000 | 1.800 | 60 | 300 | 120 | 30.000 | 30.000 | 24.000 |
| **Poland north-western** | 4.500 | 10.000 | 6.000 | 120 | 1.000 | 400 | 60.000 | 100.000 | 80.000 |
| **Sweden** | 300 | 1.000 | 600 | 12 | 10 | 4 | 60.000 | 10.000 | 8.000 |
| **Denmark** | 1.500 | 2.500 | 1.500 | 60 | 250 | 100 | 30.000 | 25.000 | 20.000 |
| **Germany northern** | 48.000 | 5.000 | 3.000 | 4.800 | 500 | 200 | 384.000 | 50.000 | 40.000 |
| **Netherlands** | 55.350 | 100 | 60 | 3.816 | 0 | 0 | 340.200 | 1.000 | 800 |
| **Belgium** | 30.000 | 50 | 30 | 1.200 | 25 | 10 | 24.000 | 100 | 80 |
| **sub total** | **148.050** | **43.450** | **26.790** | **10.434** | **3.935** | **1.574** | **1.012.200** | **446.100** | **356.880** |
| **Norway** | 252 | 5.000 | 3.000 | 25 | 50 | 20 | 2.505 | 5.000 | 4.000 |
| **UK Scot** | 150 | 0 | 0 | 6 | 0 | 0 | 3.000 | 0 | 0 |
| **UK Northern Ireland** | 3.000 | 8.000 | 4.800 | 120 | 2.000 | 800 | 60.000 | 14.000 | 11.200 |
| **UK England/Wales** | 6.000 | 5.000 | 3.000 | 600 | 2.000 | 800 | 30.000 | 10.000 | 8.000 |
| **RO Ireland** | 3.200 | 10.000 | 6.000 | 700 | 2.000 | 800 | 9.000 | 18.000 | 14.400 |
| **sub total** | **12.602** | **28.000** | **16.800** | **1.451** | **6.050** | **2.420** | **104.505** | **47.000** | **37.600** |
| **Total** | **160.652** | **71.450** | **43.590** | **11.885** | **9.985** | **3.994** | **1.116.705** | **493.100** | **394.480** |

| | **M+MS+F+J central** | **M+MS+F+J lower** | **M+MS+F+J upper** |
|---|---|---|---|
| sub Relevant for SNS | 218.290 | 15.943 | 1.815.180 |
| sub Northwest/West SNS | 57.402 | 9.921 | 189.105 |
| Total | 275.692 | 25.864 | 2.004.285 |

| **Calculated with the following settings and bandwidth** | **Estimate** | **lower** | **upper** |
|---|---|---|---|
| Number of juv per female per year | 0,60 | 0,40 | 0,80 |
| Number of satellite males (adults!) per territorial male | 2,00 | 0,20 | 5,00 |
| Number of Males per Female (not yet used as variable) | 1,00 | 0,90 | 1,10 |

## 4.3 Results A] flow model based on regional data and estimates B]

The premise regarding migration directions leads to' *countries where an out/influx can be expected'* (i.e. from Poland to Germany), and '*countries where out/influx is very unlikely to occur'* (i.e. from Sweden to Poland; see Figure 6). Combined with available basic regional data and estimates B] for these countries, and the feedback cycle with the expert team (updated until 20 01 2017), this resulted in the current structure of the flow model (Figure 6 and Table 5). This flow chart is a representation of the series of interconnected excel sheets per country, which are, in the concrete sense, the flow model A] (see excel sheets flow model).

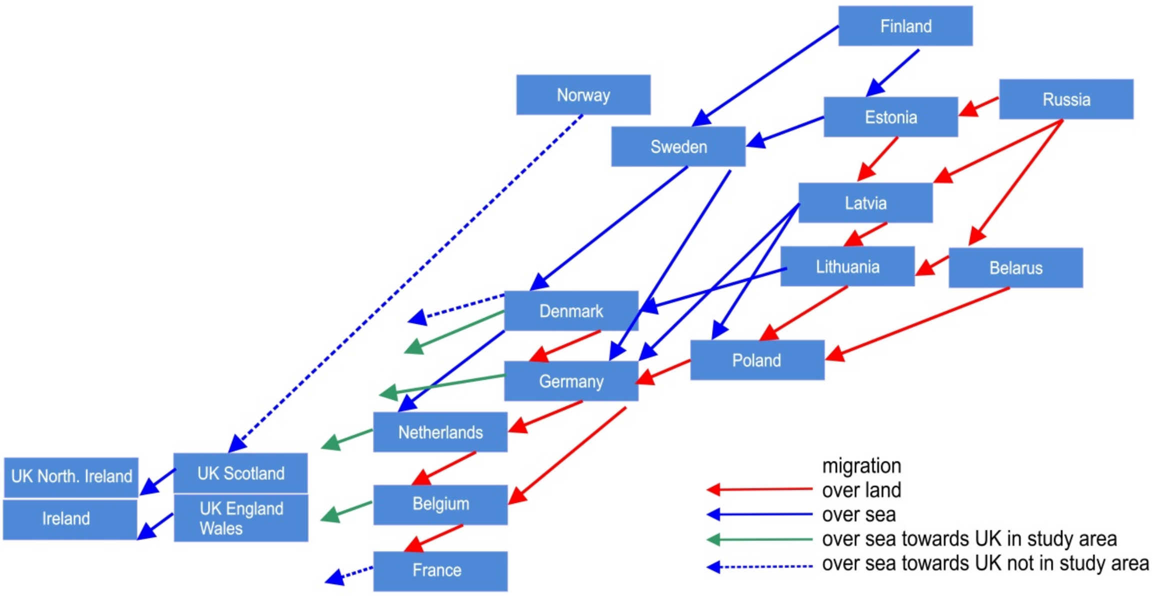



Figure 6: schematic image of the flow model of the migration of Nathusius' Pipistrelle from east/northeast to west/south-west, for that part of the population that may be expected to partially also migrate over the southern North Sea (between European and UK).
For the sake of simplicity, in this schematic approach Kaliningrad is processed in the transfer from Lithuania to Poland. General autumn migration direction is predominantly east/northeast to west/southwest, with a smaller part of the population moving in more west or more southwest directions.
Note: a flux from Sweden to Norway is not incorporated. We were not able to process this input from Norway at this stage. The outflux from Norway, however, will be north of our current study area SNS.

We 'confronted' our knowledge and expert judgement (or best informed guess) with its effect on the flow and population sizes. This interaction resulted in the currently used estimates in the flow model (status January 2017), where settings were chosen that are for now more or less acceptable for all participants.

A range of different settings for juveniles/female and satellite males/male is used to assess the reaction of the model on differences in the setting (Annex VII). The result, through using the flow model with the minimum, maximum and most central settings out of the tested range of settings, is presented in table 8[7], and Figures 7 (linear) and 8 (logarithmic). This output represents the current preliminary estimate for the number of Nathusius' Pipistrelle potentially migrating across the southern North Sea. We give the output in the numerical table as well as the linear and logarithmic histogram, to provide different images to assess the preliminary outcome.

Table 8: the current preliminary estimate for the number of Nathusius' Pipistrelle potentially migrating across the southern North Sea.

| | ***lower*** | ***central*** | ***upper*** |
|---|---|---|---|
| ***male*** | 80 | **9.428** | 163.504 |
| ***female*** | 43 | **19.226** | 521.399 |
| ***Juv*** | 17 | **11.536** | 417.119 |
| ***total*** | 140 | **40.190** | 1.102.022 |
| **settings** | juvenile/female: 0,4 - **0,6** - 0,8<br>satellite males/male: 0,2 - **2** - 5<br>(current lowest and highest settings tested) | | |

When we look at the outcome using the range of settings for J/F against the range for SM/M[8] (Table 1, Annex VII) for a series of runs, the highest central estimate produced for the total number of bats is around 50.000 individuals.

[7] **Note**: The output presented in tables 8 reflects the status of January 2017 and the accuracy of the current input.

[8] Satellite males / (territorial) males

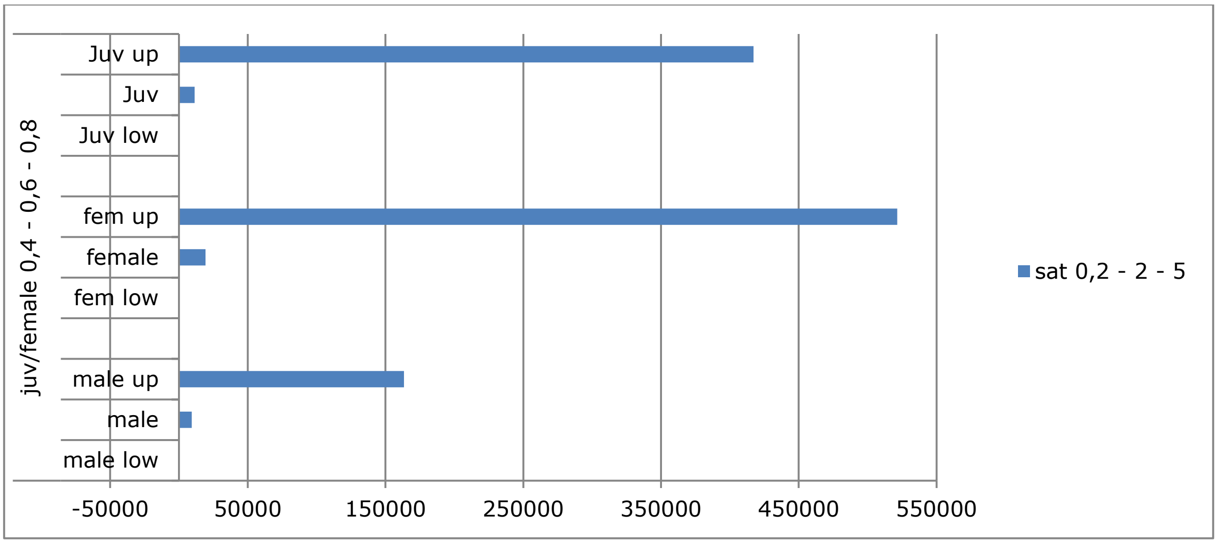



Figure 7: the current preliminary estimate for the number of Nathusius' Pipistrelle potentially migrating across the southern North Sea (linear scale).

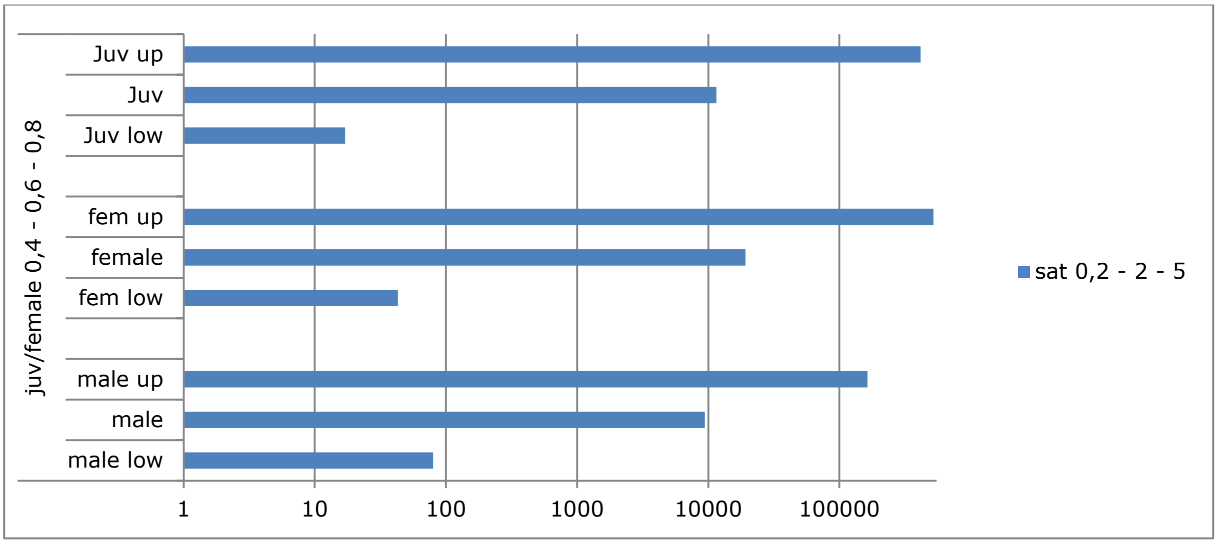



Figure 8: the current preliminary estimate for the number of Nathusius' Pipistrelle potentially migrating across the southern North Sea in a logarithmic scale.

# 5. Conclusions and discussion

## 5.1 B] regional data and estimates

Very few colleagues have been able to produce concrete data for larger areas. Data on occurrence and distribution resulting from systematic survey projects (Broekhuizen *et al.* 2016, Limpens *et al.* 1997, Limpens & Roschen 1996, 2002) are not widely available. Very few countries have data resulting from systematic surveys of the whole of their territory. There are also few data on occurrence and distribution on a smaller scale, allowing for expert judgement or estimating how many roosts (maternity, summer, mating, hibernation) might be present, and what kind of numbers of bats actually use them.

It is necessary to stimulate research regarding the data needed to answer the questions formulated in the 'Questionnaire to collect (available) basic regional information and data' (see annex II). Even when this is done for some of the elements/factors (such as J/F, satellite males/male), or only specific landscapes and/or countries, such information can be incorporated in the flow model and enhance the accuracy of the output. We recommend prioritising of research into factors that can be used for ground truthing of the model.

At this stage (status January 2017) we have a preliminary output and we have to work with large uncertainty intervals for the different elements comprising the flow model. Regarding the basic data, there are differences between countries leading towards different bandwidths of the uncertainty intervals for the countries.

The outcome or the estimation of the migration population on the southern North Sea is a result of testing the model and its basic regional input and data. More accurate input of such data is needed to produce a more accurate estimate with a lower bandwidth.

At this stage, using the combination of the basic regional data with the developed flow model was an important first step in ground truthing of the outcome of the flow model. We need to work on the availability and accuracy of the input data.

## 5.2 A] The flow model approach

The constructed model A] was consented by the expert team members (and contributors) and considered to be a good first prototype estimator.

Uncertainty regarding the output (A] based on B], status January 2017) was rather focused on the non-availability of basic regional data or estimates for most countries/regions, regarding:

- the population size of males, females and juveniles,
- the %'s of migrating individuals (Males, Females, Juveniles) as a whole, and/or
- the different proportions of migration towards different connected countries in the west/southwest direction, and
- the basic population dynamical factors such as J/F and satellite males per male.

This uncertainty is also reflected in the fact that many contributors preferred to approach the estimates, for the basic input in the model, in a conservative way. In practice this means estimating the regional female and male population sizes 'not too high', because underestimating 'feels like' a lesser mistake than overestimating. In itself this 'feeling' may well be untrue, since bats generally prove to be more abundant than intuitively assumed. Therefore, at the same time others feel that the total migrating population is probably underestimated. These signals are conflicting and are an important qualitative cue towards the process and state of the estimator (status January 2017) we need to acknowledge: the prototype estimator needs accurate input and needs ground truthing.

General factors in the flow model are now J/F (3 settings), satellite males/territorial male (4 settings), male/female ratio in offspring (1 setting). The model will improve when these factors can be made adaptable per country/region and when 'settings/values', can easily be adapted.

Mortality is a factor that may be included in an enhanced version of the flow model, preferably differentiated for M, F and J per country or region.

### Bandwidth

For 'the part of the population that migrates', we already work with a bandwidth for the different groups, males, females and juveniles. However, the percentages defining migration from one country to another (via land or sea) are not yet implemented with a bandwidth, and not yet differentiated for males, females and juveniles per country. The percentage for migration over sea is estimated per country depending on actual direction of the coastline in relation to the premises of a predominantly E/NE to W/SW autumn migration direction. The way these factors impact the migration flux in the model, can and need to be improved through implementing these bandwidths.

The flow model A] (status January 2017) is constructed in the form of a series of interrelated sheets in an excel table, and processed with concrete values. The model uses different settings, for ecological and population dynamical parameters, almost all a with specific confidence bandwidths. We recommend to assess the pros and cons of converting the model to a computer language (e.g. R?).

For Germany and Poland it is needed to investigate how to – quantitatively - differentiate between the 'general' west/southwest directed migration, and the part of the population that follows a more southerly directed path along the river valleys. The same is necessary for the more southeast directed pathway along the eastern coastline of Denmark and the German Federal country Schleswig-Holstein. And indeed more insight into a flux from Sweden to Norway is needed.

The output of the flow model A], the current resulting estimate, is a best practice estimate and naturally goes with rather high uncertainty intervals.

We stress that bandwidth value(s) should not be misinterpreted in the sense that they indicate the possibility of e.g. high numbers of individuals, where added mortality automatically results in a low impact, or where high numbers automatically result in high risk. Assessment of fatality risk in different studies concerning wind turbines on land (e.g. Brinkmann *et al.* 2011) also reveal relatively large bandwidths. In order to be able to adequately interpret the added mortality as caused by offshore wind farms, insight is urgently needed on land and at sea into the components that would allow assessment of impact on: a) the numbers of fatalities, b) the relation between abundance and risk/numbers of fatalities, as well as c) the size of the population.

We need more detail in data and ecological and population dynamical parameters. This would provide more and more accurate basic regional data, as well as more accurate estimates of general parameters. This would improve the (reliability of the) outcome of the flow model.

## 5.3 How to interpret or use the outcome

The bandwidth of the preliminary estimate (see paragraph 3.3 and annex VII) is between 100 and a 1.000.000 Nathusius' Pipistrelles migrating on the southern

North Sea, with a central estimate of around 40.000 individuals. This is the total for males, females plus juveniles and was calculated with the minimum value of the range of settings used for the lower limit and the maximum value of the range of settings for the upper.

The members of the design team as well as the other contributors agree – for now – to such values. Nevertheless we feel that more ground truthing and assessment of the population factors is needed to confirm these figures.

Comparing the estimate of the total (males+females+juveniles) population migrating on the SNS to the estimate of the total for the summer population of the potential source, is another way to try and get a sense of the functioning of the prototype estimator (Tables 8 and 9). The estimate of the central total number of bats for the potential source populations is about 5 to 6 times higher than the central total number of bats for the population migrating on the SNS. This illustrates that accuracy is still likely to be low, because it is difficult to imagine, but in itself not impossible, that between 17 and 20% of the source population would migrate on the SNS. In the current state, it is unclear whether this is predominantly a result of inaccurate estimates for the source population, the general parameters regarding J/F and SM/M, or the chosen values for the fluxes to different countries.

The estimate of the central total number of bats for the potential source populations in Latvia, Lithuania, Poland and Sweden resulting from the flow model, is about 9 to 10 times higher, than the estimate for these source populations given in Leopold *et al.* (2014) as a total for the population approaching the SNS while on migration. Both figures are estimates. In the current study, however, a more comprehensive approach is used.

The now developed estimator and especially the current outcome is far from perfect. However, this prototype gives direction and insight into the work and data needed to achieve better estimates.

# 6. Knowledge gaps and priority research questions

Organize an international programme focused on ground truthing of the factors relevant for the flow model and estimates. Many of the general parameters and country specific parameters are largely unknown.

Important actions would be: stimulate active and systematic survey of occurrence and distribution and abundance of the relevant species, their different roost types and the – average - numbers in such roost types, and preferably in relation to the landscape. For an estimate for the SNS this is most urgently needed in the range of the countries used in this study.

In relation to the urgency regarding improving population estimates of migrating bats, the surveying should preferably be done in the form of a statistical effective sample of e.g. grid cells (per country/landscape) in order to allow for quantitative extrapolation, and thus deliverance of the basic estimates for the different countries.

Investigate, per country/region, the basic ecological and population dynamical factors (such as J/F, satellite males/territorial male, mortality, % migrating, % migrating in different directions/to different countries, abundances per landscape, all for M, F and J) and the variation in such factors.

Develop methods – e.g. acoustical methods - to compare abundance of bat species on land and on see.

Organize telemetry of relevant species during migration, to verify the current estimates – deduced from available information - regarding migration directions, and quantitative differentiation between such directions. Work together with the different states in the region around the southern North Sea.

Examine the situation (weather, landscape, coastline, ..) in which individuals may stop following a coastline and start crossing open sea.

Investigate differences in (quantitative) migration parameters for the autumn and spring migration (abundance/acoustic activity; spread of individuals/abundancy in space and time [M, F and J], occurrence of funnelling, ..).

# 7. References

## 7.1 References reporting and basic data

*Note: The items in the literature list for reporting and basic data are referred in the report text and the annexes.*

Ahlén I., 1997. Migratory behaviour of bats at south Swedish coasts. Zeitschrift für Säugetierkunde 62: 375-380.
Ahlén, I., H. J. Baagøe & L. Bach, 2009. Behavior of Scandinavian bats during migration and foraging at sea. - Journal of Mammalogy, 90(6):1318–1323.
Ahlén I., L. Bach, H.J. Baagøe & Pettersson J. 2007. Bats and offshore wind turbines studied in Southern Scandinavia. Swedish EPA, Report 5571, Stockholm.
Boshamer, J.P.C. & J.P. Bekker, 2008. Nathusius' pipistrelles (Pipistrellus nathusii) and other species of bats on offshore platforms in the Dutch sector of the North Sea. Lutra 51: 17-36.
Brinkmann, R., O. Behr, I. Niermann & M. Reich (eds.), 2011. Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisions-risikos von Fledermäusen an Onshore-Windenergieanlagen. - Umwelt und Raum Bd. 4, 40-115, Cuvillier Verlag, Göttingen.
Broekhuizen, S., K. Spoelstra, J.B.M. Thissen, K.J. Canters & J.C. Buys, 2016. Atlas van de Nederlandse zoogdieren - deel 12 serie Nederlandse fauna. 300 pp. ISBN: 9789050115346Cryan, P.M. & A.C. Brown, 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines, Biol. Conserv. (2007), doi:10.1016/j.biocon.2007.05.019
Dürr, T. & L. Bach, 2004. Fledermäuse als Schlagopfer von Windenergie-Anlagen - Stand der Erfahrungen mit Einblick in die bundesweite Fundkartei. Bremer Beiträge für Naturkunde und Naturschutz Band 7. Bremen, BUND Landesverband Bremen e.V.: 253-263.
Dürr, T., 2010. Auszug aus der bundesdeutschen Schlagopferkartei, Stand 05.03.2010. Schriftl. Mitt.
Furmankiewicz, J. & M. Kucharska, 2009. Migration of bats along a large river valley in southwestern Poland. Journal of Mammalogy 90: 1310-1317.
Hobbs, M., 2014. North Sea Ferry Bat Migration Research Report. BSG Ecology.
Hutterer, R., T. Ivanova, C. Meyer-Cords & L. Rodrigues, 2005. Bat migrations in Europe: a review of banding data and literature. Naturschutz und Biologische Vielfalt 28: 1–176.
Hüppop, O. & R. Hill, 2016. Migration phenology and behaviour at a research platform in the south-eastern North Sea. Lutra 59 (1/2):5-22.
Jarzembowski, T., 2003. Migration of the Nathusius' pipistrelle *Pipistrellus nathusii* (Vespertilionidae) along the Vistula Split. Acta Theriol 48: 301. doi:10.1007/BF03194170
Jonge Poerink, B., S. Lagerveld & H. Verdaat, 2013. Pilot study bat activity in the Dutch offshore wind farms OWEZ and PAWP (2012). IMARES report C026/13.
Kurta, A., 2010. Reproductive timing, distribution, and sex ratios of tree bats in Lower Michigan. - Journal of Mammalogy, 91(3):586–592.
Lagerveld, S., B. Jonge Poerink, R. Haselager & H. Verdaat, 2014a. Bats in Dutch offshore wind farms in autumn 2012. - Lutra 57(2): 61-69
Lagerveld, S., B. Jonge Poerink & H. Verdaat, 2014b. Monitoring bat activity in offshore wind farms OWEZ and PAWP in 2013. IMARES Report C165/14.
Lagerveld, S., B. Jonge Poerink, P. de Vries & M. Scholl, 2015a. Bat activity at offshore wind farms LUD and PAWP in 2015. IMARES Report C001/2016.
Lagerveld, S. B. Jonge Poerink & P. de Vries, 2015b. Monitoring Bat activity at the Dutch EEZ in 2014. IMARES Report C094/15

Landesamt für Umwelt Land Brandenburg, 2016. Zentrale Fundkartei über Anflugopfer an Windenergieanlagen (WEA).
Lehnert, L.S., S. Kramer-Schadt, S. Schönborn, O. Lindecke, I. Niermann & C.C. Voigt, 2014. Wind farm facilities in Germany kill noctule bats from near and far. PLoS ONE 9:e103106
Leopold M.F., M. Boonman, M.P. Collier, N. Davaasuren, R.C. Fijn, A. Gyimesi, J. de Jong R.H. Jongbloed, B. Jonge Poerink, J.C. Kleyheeg-Hartman, K.L. Krijgsveld, S. Lagerveld, R. Lensink, M.J.M. Poot, J.T. van der Wal & M. Scholl 2014. A first approach to deal with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea. IMARES Report C166/14
Limpens, H.J.G.A., 2001. Beschermingsplan Vleermuizen van Moerassen. Rapport 2001.05 Vereniging voor Zoogdierkunde en Zoogdierbescherming, Arnhem, in opdracht van ExpertiseCentrum LNV Onderdeel Natuurbeheer. 84 pp.
Limpens, H.J.G.A., K. Mostert & W. Bongers, 1997. Atlas van de Nederlandse vleermuizen; onderzoek naar verspreiding en ecologie. - KNNV Uitgeverij, 260 pp.
Limpens, H.J.G.A. & R. Schulte, 2000. Biologie und Schutz gefährdeter wandernder mitteleuropäischer Fledermausarten am Beispiel von Rauhhautfledermäusen (Pipistrellus nathusii) und Teichfledermäusen (Myotis dasycneme). - Nyctalus (N.F.) 7(3):317-327.
Limpens, H.J.G.A. & A. Roschen, 1996. Bausteine einer systematischen Fledermauserfassung, Teil 1: Grundlagen. - Nyctalus (N.F.) 6, Heft 1, S. 52-60.
Limpens, H.J.G.A. & A. Roschen, 2002. Bausteine einer systematischen Fledermauserfassung. Teil 2 - Effektivität, Selektivität, und Effizienz von Erfassungsmethoden. Nyctalus (N.F.) 8/2:155-178.
Lina, P.H.C., 1990. Long-distance recoveries of Nathusius' pipistrelles Pipistrellus nathusii found or banded in The Netherlands. Lutra 33: 45±48.
Lundberg, K., 1989. Social organisation and survival of the Pipistrelle bat (Pipistrellus pipistrellus), and a comparison of advertisement behaviour in three polygynous bat species. Dissertation, Department of animal ecology, University of Lund, Sweden.
Masing, M.V., 1988. Long-distance flight of Pipistrellus nathusii banded or recaptured in Estonia. Myotis 26: 159–164.
Masing, M.V., 2011. How many bats migrate along Estonian coasts during late summer? p 37 in XIIEuropean Bat Research Symposium, Vilnius, Lithuani a, 22–26 August 2011 Lithuanian Society for Bat Conservation, Vilnius, Lithuania, 100 pp.
Mitchell-Jones, A.J., G. Amori, W. Bogdanowicz, B. Kryštufek, P.J.H. Reijnders, F. Spitzenberger, M. Stubbe, J.B.M. Thissen, V. Vohralík, and J. Zima (eds), 1999. The Atlas of European Mammals. Academic Press, London.
Niederfriniger, O., G. Rallo, C. Violani & B. Zava, 1991. Ringed Nathusius' bats, Pipistrellus nathusii, recovered in N Italy (Mammalia, Chiroptera). Atti della Societa Italiana di Scienze naturali e del Museo Civico di Storia naturale di Milano 131: 281–284.
Oldenburg, W., & H. Hackethal, 1989. Zur Migration von Pipistrellus nathusii (Keyserling u. Blasius). Nyctalus (N. F.) 3: 13–16.
O'Shea, T.J., L.E. Ellison & T. R. Stanley, 2011. Adult survival and population growth rate in Colorado big brown bats (Eptesicus fuscus). - Journal of Mammalogy, 92(2):433–443.
Petersen, A., J-K Jensen, P. Jenkins, D. Bloch & F. Ingimarsson, 2014: A review of the occurrence of bats (Chiroptera) on islands in the North East Atlantic and on North Sea installations' Acta Chiropterologica, 16, 169–195, 2014. doi: 10.3161/150811014X683381: 169-195.
Peterson, T.S., S.K. Pelletier, S.A. Boyden & K.S. Watrous, 2014. Offshore acoustic monitoring of bats in the Gulf of Maine. Northeastern Naturalist 21(1):86 – 107.
Petersons, G., 1990. Die Rauhhautfledermaus Pipistrellus nathusii (Keyserling u. Blasius, 1839) im Lettland: Vorkomen, Phänologie und Migration. Nyctalus (N. F.) 3: 81–98.

Petersons, G., 2004. Seasonal migrations of north-eastern populations of Nathusius' pipistrelle Pipistrellus nathusii (Chiroptera) Myotis 41/42: 29-56.
Petersons, G. & A. Lapina, 1990. [The results of migration studies of Pipistrellus nathusii in Latvia]. [In: The bats. Proceedings of the fifth bat research conference in the USSR, Moscov, 1990. P. P. Strelkov and V. A. Rodionov, eds]. Pensa: 73–76. [In Russian]
Roer, H., 1995. 60 years of bat-banding in Europe. Results and task for future research. Myotis 32–33: 251–261.
Rydell, J., L. Bach, M.-J. Dubourg-Savage, M. Green, L. Rodrigues & A. Hedenström, 2010. Bat mortality at wind turbines in northwestern Europe. - Acta Chiropterologica, 12(2):261–274, PL ISSN 1508-1109 © Museum and Institute of Zoology PAS doi: 10.3161/150811010X537846.
Rydell, J., L. Bach, P. Bach, L.G. Diaz, J. Furmankiewicz, N. Hagner-Wahlsten, E.-M. Kyheröinen, T. Lilley, M.V. Masing, M.M. Meyer, G. Petersons, J. Šuba, V. Vasko, V. Vintulis & A. Hedenström, 2014. Phenology of migratory bat activity across the Baltic Sea and the South-Eastern North Sea. Acta Chiropterologica, 16 (1): 139-147.
Schaub, M., O. Gimenez, A. Sierro & R. Arlettaz, 2007. Use of Integrated Modeling to Enhance Estimates of Population Dynamics Obtained from Limited Data - Conservation Biology Volume 21, No. 4, 945–955.
Šuba, J., G. Petersons & J. Rydell, 2012. Fly-and-forage strategy in the bat Pipistrellus nathusii during autumn migration. Acta Chiropterologica 14: 379–385.
Voigt, C.C., A.G. Popa-Lisseanu, I. Niermann, S. Kramer-Schadt, 2012. The catchment area of wind farms for European bats: A plea for international regulations. Biological Conservation 153 (2012) 80–86.
Voigt, C.C. & L.S. Lehnert, G. Petersons, F. Adorf & L. Bach, 2015. Wildlife and renewable energy: German politics cross migratory bats. - Eur J Wildl Res.
Voigt, C.C., O. Lindecke, S. Schönborn, S. Kramer-Schadt & D. Lehmann, 2016. Habitat use of migratory bats killed during autumn at wind turbines. Ecological Applications, 26(3):pp. 771–783.
Walter, G., H. Matthes & M. Joost, 2007. Fledermauszug über Nord- und Ostsee — Ergebnisse aus Offshore-Untersuchungen und deren Einordnung i das bisher bekannte Bild zum Zuggesschehen. Nyctalus (N.F.), 12.

## 7.2 Literature basic regional data

*Note: The items in the literature list for regional basic data are received via the questionnaires and are input for the estimates in the excel sheets per country. These are not specifically referred to in the report text.*

Ahlén, I., 2011a. Fladdermusfaunan i Sverige. Arternas utbredning och status. Kunskapsläget 2011. Fauna och flora 106: 2-19.
Ahlén, I., 2011b. Pipistrellus nathusii, trollpipistrell. Artdatabanken, SLU, Uppsala. http://artfakta.artdatabanken.se/taxon/100111
Baagøe, H. J., 2001. Danish bats (Mammalia: Chiroptera): atlas and analysis of distribution, occurrence, and abundance. Steenstrupia 26:1–117.
Baagøe, H.J., 2007: Troldflagermus Pipistrellus nathusii (Keyserling & Blasius, 1839). In Baagøe. H.J. & T.S. Jensen, 2007: Dansk Pattedyratlas. Gyldendal. s. 66-69
Baagøe, H.J., 2011: Bornholms flagermus- status 2010. Natur på Bornholm Nr. 9, 2011, s 22-30. BugBook Publishing.
Baagøe, H., & D. Bloch, 1994: Bats (Chiroptera) in the Faroe Islands. Frödskaparrit, pp. 83-88. Thorshavn.

Baagøe, H.J. & E.T. Fjederholt, 2014: Dværgflagermus (Pipistrellus pygmaeus)- første sikre fund fra Bornholm – og lidt om de to andre Pipistrellus-arter. Natur på Bornholm. Nr. 12, 2014, s 8-12. BugBook Publishing. [English summary: Soprano bat (Pipistrellus pygmaeus) – first positive records from Bornholm.]
Battersby, J. (Ed) & Tracking Mammals Partnership, 2005. UK Mammals Species Status and Population Trends. First Report by the Tracking Mammals Partnership. JNCC/Tracking Mammals Partnership, Peterborough.
Borkenhagen, P., 1993. Atlas der Säugetiere Schleswig-Holsteins. Landesamt für Naturschutz. 129 pp.
Broekhuizen, S., K. Spoelstra, J.B.M. Thissen, K.J. Canters & J.C. Buys (eds.), 2016. Atlas van de Nederlandse zoogdieren - herkenning, verspreiding & leefwijze. Deel 11 serie Nederlandse fauna. 300 pp. ISBN: 9789050115346
Elmeros, M, J.D. Møller & H.J. Baagøe, 2015: Part A Bat studies 2013 in: Therkildsen O.R. & M. Elmeros 2015: First year post- construction monitoring of bats and birds at wind turbine test center Østerild.
FEBI, 2013. Fehmarnbelt Fixed Link EIA. Fauna and Flora – Bats of the Fehmarnbelt Area – Baseline Volume I Report No. E3TR0016 Report: 65 pages
FEBI, 2013. Fehmarnbelt Fixed Link EIA. Fauna and Flora – Impact Assessment - Bats of the Fehmarnbelt Area. Report No. E3TR0017. Report: 66 pages
Gerell, R., 1987. Flyttar svenska fladdermöss? Fauna och Flora 82:79–83.
Isaksen, K., P.O. Syvertsen, J. van der Kooij & H. Rinden, (red.), 1998. Truete pattedyr i Norge: faktaark og forslag til rødliste. – Norsk Zoologisk Forening. Rapport 5. (182 s.)
Isaksen, K. og Olsen, K.M. 2007. Kartleggingsarbeid utført av Norsk Zoologisk Forenings flaggermusgruppe. – Fauna 60 (3–4): 176–182.
Isaksen, K., K.M. Olsen & P.O. Syvertsen, 1993. Kartlegging av pattedyrenes utbredelse i Norge – en prosjektorientering. – Fauna 46 (1): 3–9.
Isaksen, K. (Red.), M. Klann, J. Van Der Kooij, , T.C. Michaelsen, , K.M. Olsen, , T. Starholm, C.F. Sunding, , M.F. Sunding & P.O. Syvertsen, 2009. Flaggermus I Norge. Kunnskapsstatus Og Forslag Til Nasjonal Handlingsplan. Norsk Zoologisk Forening. Rapport 13. 124 S. (Isbn 978-82-7857-014-2).
Kapteyn, K., 1995. Vleermuizen in het landschap; over hun ecologie, gedrag en verspreiding. Schuyt & Co., Haarlem.
Limpens, H.J.G.A., K. Mostert & W. Bongers, 1997. Atlas van de Nederlandse vleermuizen; onderzoek naar verspreiding en ecologie. - KNNV Uitgeverij, 260 pp.
National Report on the Implementation of the Agreement on the Conservation of Bats in Europe: United Kingdom (1999).
National report on the implementation of the Agreement on the Conservation of Populations of European Bats: United Kingdom 2010-2013.
National report on the implementation of the Agreement on the Conservation of Populations of European Bats: 2010-2013: the Netherlands.
Roche, N., T. Aughney, N. Kingston, D. Lynn & F. Marnell, 2015. Records for Nathusius' pipistrelle (Pipistrellus nathusii) in Ireland from a car-based bat monitoring scheme. Irish Naturalists' Journal 34(2): 83-88.
Russ, J.M., 1999. The Microchiroptera of Northern Ireland: community composition, habitat associations and ultrasound. PhD thesis. The Queen's University of Belfast.
Russ, J.M., 2014. Nathusius' pipistrelle in Great Britain & Ireland. Available at: http://www.nathusius.org.uk (accessed 10th September 2016).
Russ, J.M.. 2012. British Bat Calls: A Guide to Species Identification. Pelagic Publishing, Exeter, UK.
Russ, J.M., A.M. Hutson, W.I. Montgomery, P.A. Racey & J. R. Speakman, 2001, The status of Nathusius' pipistrelle (Pipistrellus nathusii Keyserling & Blasius, 1839) in the British Isles. J. Zool., Lond. 254:91-100
Syvertsen, P.O., P. Shimmings & K. Isaksen, 1996. The Norwegian Mammal Fauna: Status And Atlas Mapping. Hystrix, (Ns.) 8 (1-2): 91-95

Skov, H., M. Desholm, S. Heinänen & T.W. Johansen, 2015: Kriegers Flak Offshore Wind Farm Environmental Impact Assessment Technical background report Birds and bats. A report prepared for Energinet.dk as part of the EIA for Kriegers Flak Offshore Wind Farm. The report is prepared by Danish Center for Environment and Energy (DCE) at Aarhus University and DHI in collaboration with NIRAS. January 2015

Verkem, S., J. De Maeseneer, B. Vandendriessche, G. Verbeylen, & S. Yskout, (Ed.) 2003. Zoogdieren in Vlaanderen: ecologie en verspreiding van 1987 tot 2002. Natuurpunt Studie, JNM Zoogdierenwerkgroep: Mechelen. ISBN 90-77507-01-9. 451 pp.

## 7.3 Websites regional data

http://www.batmap.de/web/start/karte;jsessionid=4E67E0846C15AF90FC4E6A0031AEDD8C

https://www.verspreidingsatlas.nl/zoogdieren
http://www.nathusius.org.uk/Distribution.htm
http://www.bats.org.uk/pages/nathusius_pipistrelle.html#Distribution

## 8. Annexes

I) Annex 1 : Questionnaire to collect (available) basic regional information and data

II) Annex 2: Assessment of relevant species

III) Annex 3: Summary feedback basic regional information and data

IV) Annex 4: Premises regarding the migration flow model

V) Annex 5: Summary complex geographic interconnection between distribution, mating/reproduction and migration of the Nathusius' pipistrelle

VI) Annex 6: Summary feedback on flow model

VII) Annex 7: Analysis of the reaction of the prototype estimator (the flow model) through using a range of settings for the number of juveniles/female and satellite males/male.

VIII) Annex 8: Preliminary estimates for migrating Nathusius' pipistrelle over the southern North Sea - histograms of test runs January 2017

## Annex 1:Questionnaire to collect (available) basic regional information and data

Tables 1 to 6 present the questions used to assess B] basic regional data for the estimator, as well as information regarding the (non)-availability of such data for the specific states, nations or regions.

Table 1: Questionnaire to collect data on bat maternity roosts/colonies.

| **MATERNITY COLONIES** |
|---|
| |
| **occurrence** |
| is the species present in your country? |
| can you give an already existing estimate of the population size (EHD/EUROBATS reporting e.g. all individuals year round)? |
| please add sources and publications |
| |
| **maternity colonies/roosts (colony = network of roosts)** |
| Are there maternity colonies (network of roosts)? |
| can you give an estimate of how many maternity colonies exist? |
| can you give an estimate of the number or proportion of 'investigated' maternity colonies? |
| can you give an estimate of the average number of individuals (females) in one colony (network of roosts)? If only the number of total individuals (females and offspring) is known, please indicate so under remarks |
| can you indicate whether the number of juveniles per female differs from 1? -if known |
| **population estimates / your expert interpretation of above information** |
| estimate of population (females) based on numbers of maternity roosts and average number in maternity roosts |
| Does this number provide a good estimation of the population number (of females) in your expert opinion? If not: what would be a good number? |
| |
| **Area's if possible** |
| can you describe preferable foraging grounds for the species? |
| can you give an estimate of the average area ([foraging] home range) used by one colony? |
| can you give an estimate (hectares or %tage region/country) of the available area that could be qualified as habitat (roosts and foraging) for the species? |
| please add a sketch/sketches on a map where appropriate? |
| please add sources and publications |

Table 2: Questionnaire to collect data on bat summer roosts.

| |
|---|
| **Summer roosts** |
| |
| **Does the information below pertain to maternity roosts as well? If distinction between summer and maternity roosts can be made, please use the two separate sheets.** |
| **summer roosts (individual roosts, network not known)** |
| can you give an estimate of how many summer roosts exist? |
| can you give an estimate of the number or proportion of investigated summer roosts? |
| please add sources and publications |
| can you give an estimate of the average number of individuals in one summer roost? |
| can you indicate whether the number of individuals includes juveniles |
| **population estimates / your expert interpretation of above information** |
| estimate of population (all individuals) based on numbers of summer roosts and average number in summer roosts |
| Does this number provide a good estimation of the population number (of females) in your expert opinion? If not: what would be a good number? |
| |
| **Area's if possible** |
| can you give an estimate of the average area ([foraging] home range) of a summer roost? |
| can you give an estimate (hectares or %-age region/country) of the available area that could be qualified as habitat (roosts and foraging) for the species? |
| please add a sketch/sketches on a map where appropriate? |
| please add sources and publications |

Table 3: Questionnaire to collect data on bat mating roosts and clusters.

| |
|---|
| **Mating roosts and clusters** |
| |
| **Occurence** |
| are there mating sites/territorial males? |
| are there clusters of mating sites/clusters of territorial males? |
| |
| **Mating roosts and/or clusters** |
| can you give an estimate of how many (clusters of) mating sites exist? |
| can you give an estimate of the number or proportion of investigated (clusters of) mating sites/territorial males? |
| |
| can you give an estimate of the average number of individuals in one mating site/cluster? |
| can you give an estimate of the average turnover of females in one mating site/cluster? |
| can you estimate the average number of sites where 1 female could be counted? |
| |
| **population estimates / your expert interpretation of above information** |
| estimate of population (all individuals) based on numbers of mating roosts and average number in (clusters of) mating roosts |
| Does this number provide a good estimation of the population number in your expert opinion? If not: what would be a good number? |
| |
| |
| **Area's if possible** |
| can you give an estimate (hectares or %tage region/country) of the available area that could be qualified as habitat (roosts and foraging) for the species? |
| please add a sketch/sketches on a map where appropriate? |
| please add sources and publications |

Table 4: Questionnaire to collect data on bat hibernation roosts.

| **Hibernation** |
|---|
| |
| **hibernation roosts** |
| are there hibernation roosts known? |
| can you give an estimate of how many hibernation roosts might exist? |
| can you give an estimate of the number or proportion of investigated hibernation roosts? |
| |
| can you give an estimate of the average number of individuals in one hibernation roost? |
| |
| **population estimates / your expert interpretation of above information** |
| estimate of population (all individuals) based on numbers of hibernation sites and average number in hibernation sites |
| Does this number provide a good estimation of the population number in your expert opinion?  If not: what would be a good number? |
| |
| **area's if possible** |
| can you give an estimate of the available area that could be qualified as habitat (hibernation roosts) for the species? |
| please add a sketch/sketches on a map where appropriate? |
| please add sources and publications |

Table 5: Questionnaire to collect data on bat migration, part 1.

| |
|---|
| **migration** |
| |
| **Occurence** |
| is there evidence of migration for the species? |
| what is the evidence? |
| |
| Pathways? |
| what is the landscape/are the landscape structures used for migration? |
| what evidence is there for migration over land? |
| what evidence is there for migration along the sea shore? |
| what evidence is there for migration over sea? |
| |
| **Direction** |
| is there an idea on the direction(s) of the migration? |
| what evidence is there to support this notion? |
| please add a sketch on a map where appropriate? |
| |
| would you recognize one <u>general</u> direction or <u>distinct directions</u>? |
| if there is one general direction: what is the general direction of migration? |
| if there are distinct directions: what are the possible different directions that might be distinguished? Use the below cells to indicate appropriate %-age per direction |
| South |
| South East |
| East |
| North East |
| North |
| North West |
| West |
| South West |

Table 6: Questionnaire to collect data on bat migration, part 2.

| **migration** |
|---|
| |
| **Size** |
| can you give an estimate of what %-age of your national/regional population would be migrating? |
| please add a sketch/sketches on a map with %-ages where appropriate? |
| |
| **Distance (if known)** |
| if one general direction: can you give an estimate of the migration distance? |
| can you give an estimate of the migration distance per specific migration direction? |
| South |
| South East |
| East |
| North East |
| North |
| North West |
| West |
| South West |
| please add sources and publications |
| |
| **funnel or broad front** |
| is migration funnelled, or more like a broad front? |
| are there areas where 'funnelling' would be the right description? |
| are there areas where 'a broader front' would be the right description? Can you add those to the map? |
| can you give an estimate of the available area that could be qualified as habitat migration for the species? |
| please add a sketch/sketches on a map with %-ages where appropriate? |
| please add sources and publications |

## Annex 2: Assessment of relevant species

Based on Leopold *et al.* 2014, updated with new information, an assessment of the relevance of species to work with in the design of the prototype estimator is performed. The relevance of a species is deduced from

- the occurrence of species offshore at sea,
- the abundance or (relative) numbers that might be present offshore (expert judgement: abundance offshore is related to abundance onshore),
- the fatality risk that might arise from the species behaviour (such as migration, flight height, accumulation around wind turbines), as well as
- the feasibility of assessing basic regional information B] necessary for the flow model A].

**Species potentially present on the (southern North) sea.**

So far, 11 European bat species have been observed above sea in the north western regions in Europe (Ahlén *et al.* 2009, Boshamer & Bekker 2008, Jonge Poerink *et al.* 2013, Lagerveld *et al.* 2014a,b, 2015a,b. Petersen *et al.* 2014, Walter *et al.* 2007).

These are: Daubenton's Bat (*Myotis daubentonii*), Pond Bat (*Myotis dasycneme*), Nathusius' Pipistrelle (*Pipistrellus nathusii*), Common Pipistrelle (*Pipistrellus pipistrellus*), Soprano Pipistrelle (*Pipistrellus pygmaeus*), Leisler's Bat (*Nyctalus leisleri*), Common Noctule (*Nyctalus noctula*), Northern Bat (*Eptesicus nilssonii*), Serotine (*Eptesicus serotinus*), Particoloured bat (*Vespertilio murinus*) and Long-eared Bat (*Plecotus auritus*).

Since 1988 collection of data from found offshore platforms – roughly representing a sample for the southern North Sea - revealed Nathusius' Pipistrelle (32x), Noctule (2x), Northern Bat (2x), Serotine (1x) and Particoloured Bat (5x), with the highest incidence for Nathusius' Pipistrelles. For Nathusius' Pipistrelles and most other bat species (with the exception of the Noctule) no bias towards platforms closer to the shore was observed. Bats were recorded at distances of 60-80 km from the shore (Boshamer & Bekker 2008; Boshamer pers. comm.). These are distances of 1/3 to 1/2 of the distance between the southwest of the Netherlands and the UK, and larger than the distance between Calais and the UK.

Table 1: bats recovered from off shore oil platforms between 1988 and 2014[9] (after Boshamer & Bekker 2008, pers. comm. )

| | # | % |
|---|---|---|
| Nathusius' Pipistrelle | 32 | 76 |
| Noctule | 2 | 5 |
| Northern Bat | 2 | 5 |
| Serotine | 1 | 2 |
| Particoloured Bat | 5 | 12 |
| | 42 | 100 |

In (pilot) studies using real time recorders in wind parks on the southern North Sea, Nathusius' Pipistrelle, Common Pipistrelle, Noctule and probably Particoloured Bat were recorded off shore. The majority of recordings could be attributed to the Nathusius' Pipistrelle (Jonge Poerink *et al.* 2013, Lagerveld *et al.* 2014a,b, 2015a, b). Common Pipistrelle, Pond Bat and Daubenton's Bat were recorded on a site on the beach (Lagerveld *et al.* 2015b). In some recordings from these studies the species comprising the 'Nyctaloid'-group with the genera *Nyctalus*, *Vespertilio*, and *Eptesicus*, could not be identified to the level of species.

Based on ringing, long distance migration during which seas potentially have to be crossed, is known for the Nathusius' pipistrelle, the Noctule and the Parti-coloured bat (Hutterer *et al.* 2005, Roer 1995). These data predominantly reflect east/north east towards west/south west migration directions. (Hutterer *et al.* 2005, Jarzembowski 2003, Limpens & Schulte 2000, Limpens 2001, Lina 1990, Massing 1988, Mitchell-Jones *et al.* 1999, Niederfriniger 1991, Oldenburg & Hackethal 1989, Petersons 1990, Petersons & Lapina 1990, Roer 1995, Russ *et al.* 2001, Voigt *et al.* 2012, 2016). Although ringed individuals from the larger ringing schemes from Latvia and northern Germany would not need to cross the sea, observations on e.g. Nathusius' Pipistrelle and Noctule in southern Sweden clearly indicate that the sea is crossed (Ahlén *et al.* 2009).

In 2013 the first Nathusius' Pipistrelle ringed in the UK (ringed 2012 by Daniel Hargreaves[10] Blagdon lake/Somerset) was recovered on mainland Europe in the Netherlands (December 2013 by Teddy Dolstra). Two ringed Nathusius' Pipistrelles, one from Latvia and one from Lithuania, were recovered in Sussex and Kent. These findings clearly showed that Nathusius' Pipistrelles do cross the North Sea.

## Assessment of relevancy of different species

[9] Due to changes in personnel, in the last few years the contact to those people from this industry willing to collect found bats was lost.

[10] http://www.bats.org.uk/pages/national_nathusius_pipistrelle_project.html

On the off shore platforms 75% (N=42) of the observations are Nathusius' pipistrelle, with 2 and 5 % for the Noctule and Party-coloured bat (Boshamer & Bekker 2008; Boshamer pers. comm.).

The data from the real time recorders on off shore sites are even more skewed towards the Nathusius' Pipistrelle, with over 95% of acoustic recordings for Nathusius' Pipistrelle and only few Nyctaloids, and/or Noctules and Particoloured Bats (Jonge Poerink *et al.* 2013, Lagerveld *et al.* 2014a,b, 2015a,b). Differences in detection range of a species echolocation (e.g. peak frequencies, loudness, pulse length, duty cycle), in relation to their flight style (flight height, directionality of flight, hunting versus commuting), bias these data.
Data on ringed bats crossing to the UK are only known for the Nathusius' Pipistrelle (Hargreaves pers. Comm./UK national Nathusius' pipistrelle project).

In fatality searches in onshore wind farms, the Noctule and Nathusius' Pipistrelle are the most commonly found species with between 30 and 50% of casualties for the Noctule and between 25 and 35% for Nathusius' Pipistrelle (e.g. Brinkmann *et al.* 2011, Dürr/LU Land Brandenburg 2016, Dürr & Bach 2004, Rydell *et al.* 2010).

Table 2: indication of relevance for assessment of impact of off shore wind turbines on species. The number of dots indicate a relative incidence for that label/row.

| **species observed off shore →** | | **Nathusius' pipistrelle** | **Noctule** | **Parti-coloured bat** | **Common pipistrelle** | **Soprano pipistrelle** | **Daubenton's bat** | **Pond bat** | **Leisler's bat** | **Serotine** | **Northern bat** | **Brown long-eared bat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| observation on off shore oil platform | | ●●●●● | ● | ●● | | | | | | ● | ● | |
| acoustic observation off shore on southern North Sea | | ●●●●●● | ● | ● | | | | | | | | |
| banded individuals potentially crossing sea | | ●●●●● | ●●●● | ●● | | | | | ●● | | | |
| banded individuals crossing between UK and mainland | | ●●●●●● | | | | | | | | | | |
| casualties on land | | ●●●● | ●●●●●● | ● | ●●● | ● | * | * | ● | ● | ● | * |

The above data are all biased in various ways, but can still roughly be used to try to deduce which species is relevant for impact assessment in relation to the development of off shore wind parks (table 2).

The prevalence of the Nathusius' Pipistrelle both as a fatality at wind turbines on land, as in observations on (the southern North) Sea, and migration between UK and mainland Europe, indicate this species as a relevant species in the assessment of impact of off shore wind turbines on the species (Table 2).

The Noctule has an even higher incidence of fatality in onshore wind farms, but is much less prevalent in the available (acoustic) data from the southern North Sea. The Particoloured Bat has a lower incidence of fatality on land, but is also much rarer than e.g. the Noctule and Nathusius' Pipistrelle. Compared to the Noctule, observations of the Particoloured Bat offshore are little higher on the oil platforms, and of comparably low level in acoustic observations.
For both of the latter two species the evidence of, and expected (potential) presence on the southern North Sea (ringing, acoustic, off shore oil platforms), are much higher than the rest of the other species known to occur at sea. For these two species this indicates that it is worth trying to assess the impact of offshore wind turbines on the species (Table 2).

The Common Pipistrelle can reveal a high incidence of fatality at onshore wind farms, in situations where turbines and maternity roosts are in relatively close proximity. The species is not observed on the oil platforms nor in the acoustic data from the southern North Sea. For the other species known to potentially occur over sea, there are low to accidental observations of fatalities at wind turbines on land, and no acoustic data from the southern North Sea. Although a fatality of such a species at a wind turbine at sea cannot be 100% ruled out, based on current knowledge the fatality risk will be low (table 2).

Systematic data on occurrence and distribution (e.g. Limpens & Roschen 1996, 2002) of a species, such as resulting from national mapping projects, are not available for all national territories around the southern North Sea.
Data directly related to the offshore situation (oil platforms, acoustic studies offshore and on islands of the coast) are scarce, and certainly on this large geographical scale. The available data are predominantly of Nathusius' Pipistrelle.

Current data collection concerned with wind turbines offshore, on islands off the coast and in wind farms close to the coast is steadily increasing the available information.

Due to the relative lack of data for the Noctule and Particoloured Bat, we focus on the Nathusius' Pipistrelle.

## Annex 3: Summary feedback B] basic regional information and data

Table 1: overview feedback B] basic regional information and data

| | consent approach basic estimates | elaborate data and estimates | limited data not including estimates |
|---|---|---|---|
| | | | |
| Finland | 1 | | 1 |
| Estonia | | | |
| Belarus | | | |
| Latvia | 1 | | 1 |
| Lithuania | | | |
| Poland north-western | | | |
| Sweden | 1 | | 1 |
| Denmark | 1 | | 1 |
| Germany north | 1 | | 1 |
| Netherlands | 1 | 1 | 1 |
| Belgium | 1 | | 1 |
| | | | |
| Norway | 1 | | 1 |
| | | | |
| UK Scot | 1 | 1 | |
| UK Northern Ireland | 1 | 1 | |
| UK England/Wales | 1 | 1 | |
| UK England/Wales | 1 | 1 | |
| RO Ireland | 1 | 1 | |
| | | | |
| France | 1 | | 1 |
| Portugal | 1 | | |

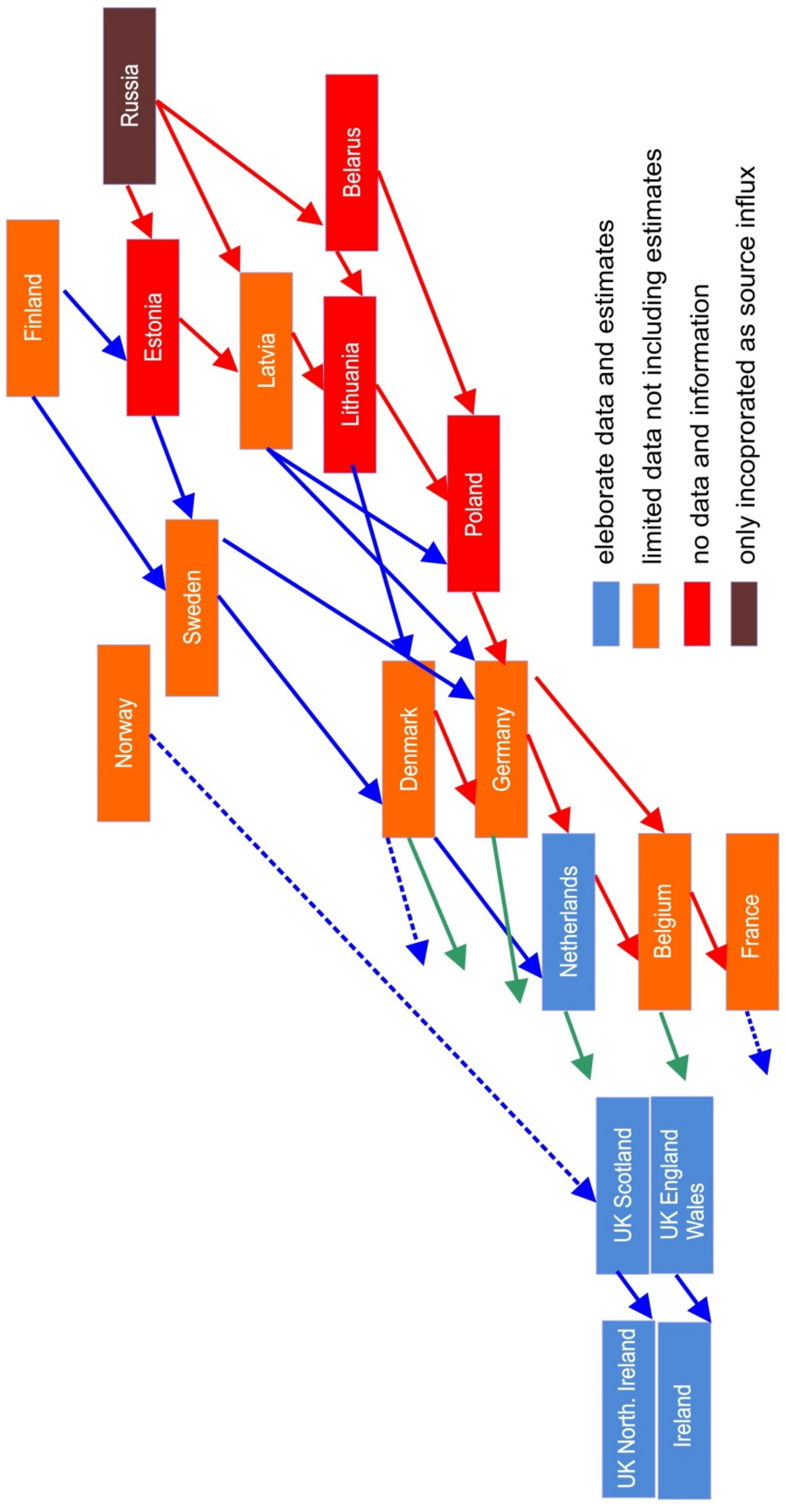



Figure 1: overview feedback basic regional information and data (data processed till 20 Jan 2017)

Table 2: summary feedback B] basic regional information and data

| | Regional data and estimates → | General input approach | Data / estimates |
|---|---|---|---|
| **Germany** | Lothar & Petra Bach | x | Not able to estimate through lack of data |
| | Johanna Hurst | x | Outside model region; lack of data |
| **UK** | Kathrine Boughey | x | Input via Jon Russ |
| | Jon Russ, | x | Estimates England, Estimates Northern Ireland, no data available for Scotland and Wales |
| John Haddow, Susan Swift, Daniel Hargreaves, Fiona Mathews | | x | Input via Jon Russ |
| **RO Ireland** | Niamh Roche | x | Data on ROI |
| | Tina Aughney | x | Input via Niahm Roche |
| **Scandinavian region** | | | |
| **Norway** | Jeroen van der Kooij | x | No countrywide data, overview of such data as are available |
| | Tore Chr Michaelsen | x | Input local observation points, no countrywide data |
| **Sweden** | Johnny de Jong | x | No countrywide data, overview of such data as are available |
| **Denmark** | Hans Baagoe + Esben Terp Fjederholt | x | No countrywide data, overview of such data as are available |
| Ingemar Ahlén, Jan Durinck, Morten Christensen, Morten Elmeros, Thomas W. Johansen and Julie Dahl Møller | | x | Input via Baagoe and Fjederholt |
| **Finland** | Eeva-Maria Kyheröinen | x | No countrywide data, overview of such data as are available |
| **Baltic region** | | | |
| **Latvia** | Gunars Peterson | x | No countrywide data, overview of such data as are available |
| **Estonia, Lithuania, Belarus, Poland** | | | |
| **Belgium** | Bob Vandendriessche | x | No countrywide data, overview of such data as are available, estimate based on road migration front. |
| | SMITS Quentin | | |
| **France** | Marie-José Dubourg- | x | No countrywide data |
| Thomas Le Campion, Dorothee Jouan, Diane Anxionnat | | x | Input local observation points, no region wide data |
| **Iberic region** | | | |
| **Portugal** | Luisa Rodrigues | x | Outside model region; lack of data |
| **Nederland** | Herman Limpens Eric Jansen, | x | Estimates for the Netherlands |
| | Peter Twisk | x | No input |
| Jasja Dekker, A-J Haarsma, Jan Boshamer, Theo Douma | | x | Input local observation points |
| Marcel Schillemans | | | |
| | | | |

## Annex 4: Premises regarding the migration flow model

**Note**: This annex is a more elaborate version of the description of the premises described in paragraph 2.5.

a) In this study, due to the relative lack of data for the Noctule and Parti-coloured bat, we will focus on the Nathusius’ pipistrelle. Although of course there are differences between the species, we think that developing and testing the approach for the Nathusius’ pipistrelle, will make future application for other species easier. The knowledge gaps identified for the Nathusius’ pipistrelle will only be larger for the other species.

b) In our interpretation we focus on information related to the autumn migration period.

c) Information from the questionnaires and other contributions of the respondents/participants in this study, indicate a main migration direction from east/north east to west/south west. However a smaller part of the population may have more west or more southwest directions. This is in accordance with literature (Hutterer *et al.* 2005, Jarzembowski 2003, Limpens & Schulte 2000, Limpens 2001, Lina 1990, Masing 1988, Mitchell-Jones *et al.* 1999, Niederfriniger 1991, Oldenburg & Hackethal 1989, Petersons 1990, Petersons & Lapina 1990, Roer 1995, Russ *et al.* 2001, Voigt *et al.* 2012, 2016).

   At the same time migration in more southward direction may be observed along coastlines (e.g. along the Dutch province of North-Holland) and through river valleys (input L. & P. Bach, J. Hurst) such as the Rhine valley and the Elbe valley, and even in south/southeast direction along the east coast of Denmark (input Baagøe and Terp Fjederholt). Drift cannot be excluded (Hüppop & Hill 2016).

   We use the premises of an east/north east to west/south west migration direction in our model, although this is most likely a simplification of reality. Applying this assumption results in countries where exchange (influx/outflux) can be expected (i.e. from Poland to Germany) and countries where out/influx is very unlikely to occur (i.e. from Sweden to Poland).

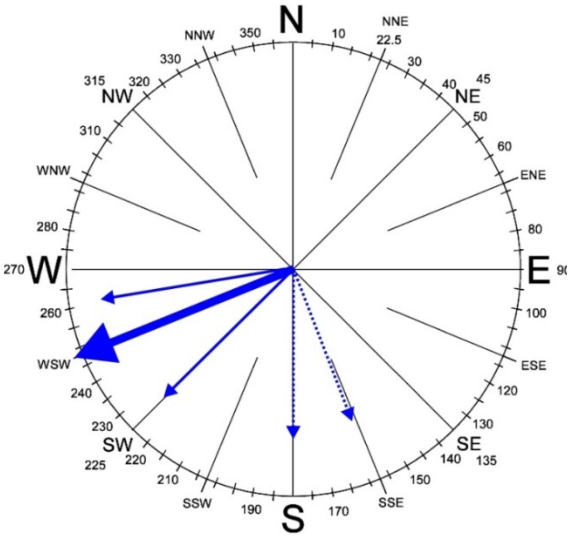


Figure 1: Main migration direction, and other observed directions (see text).

d) Almost independent from the geographical location, data from studies related to wind turbines on land in Europe, reveal peaks of observations of Nathusius' Pipistrelles in autumn (questionnaires and literature: Ahlén 1997, Ahlén *et al.* 2007, 2009; Brinkmann *et al.* 2011; Lagerveld *et al.* 2014a). This suggests a broader migration front rather than narrow corridors. However, the relative numbers observed in such studies, as well as visual observation in the landscape, suggest the existence of funnelling along the coast and along river valleys. This may also lead to a migration direction following the coast line or river valley in a more north to south direction.

e) Larger areas of water will be crossed, probably mostly at sites where there is no other (logical) choice (see e.g. : Ahlén 1997, Ahlén *et al.* 2007, 2009), e.g. in situations such as in
- Falsterbo, or the south points of Isles like Gotland and Öland in Sweden, where all directions other than back (back north/north-east) lead to open water,
- Westkapelle (and the west point of other islands) in the south west of the (province of Zeeland in the) Netherlands, where the coastline turns land inward (direction SE and E), and following the coastline would mean a large deviation of the general migration direction,
- and probably also in situations where the coastline deviates from the general migration direction for long distances (long periods of flying), such as found along the N/S coast lines of the west coast of Denmark and the province of North-Holland in the Netherlands.

f) Based on the selection of relevant species and the developed approach, source and target areas of bats migrating above and/or along the coast of the southern North Sea are identified. Calculating from the northern and north-eastern most of the countries around the southern North Sea, and based on a rough interpretation of the geographical migration pattern of the Nathusius' Pipistrelle (www.grida.no[12], Limpens & Schulte 2000; see fig. 3) we constructed a flow model for the setting given in fig. 6.

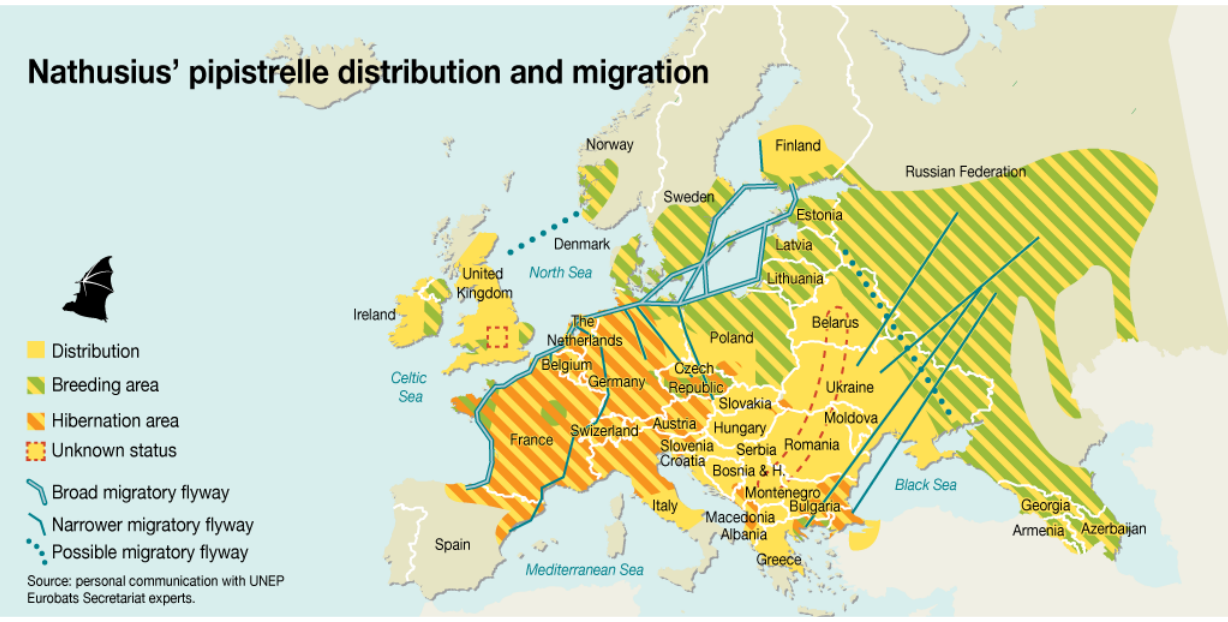


Figure 2: Nathusius' pipistrelle distribution and migration (From collection: Living Planet: Connected Planet, Rapid Response Assessment, Riccardo Pravettoni, UNEP/GRID-Arendal, 2011). Ad figure 2: Note: We use this illustration because it gives a quit good overview, but since 2011 new data is available. Please note, however, that no maternity groups are ever discovered in Norway, nor were any of the captured Nathusius' pipistrelles females (J. v.d. Kooij, pers. Com.). A possible flux from Sweden to Norway is not taken into account (J. v.d. Kooij, pers. Com.). Also all areas without breeding, in the sense of occurrence of maternity sites, are qualified as hibernation area. The fact is that many sites with (clusters of) mating roosts are found in both the maternity and hibernation area.

We incorporated Norway, UK (Scotland, Northern-Ireland, England and Wales), the Republic of Ireland, Finland, Sweden, Estonia, Latvia, Lithuania, north western part of Poland, Denmark, northern part of Germany, the Netherlands and Belgium in the flow model.

The migrating bats (the 'migration flow of individuals') of these countries might be arriving at the southern North Sea, where populations migrating from/though Norway would end up in the northern North Sea. Norway is included, however, because their outflux may be an influx to Scotland and Northern Ireland. Those migrating from/through Luxemburg, the middle and

---

[12] http://www.grida.no/graphicslib/detail/nathusius-pipistrelle-distribution-and-migration_18cb

south of Germany, middle and east of Poland, Czech Republic et cetera would end up more to the south of the current study area, in the direction of France, Switzerland, Italy, and Spain, or even more south in central southern Europe.

g) In this study, some of the countries will be regarded as being 'source countries' (e.g. Finland or Norway), where based on the distribution of the species, in our model we assume that there is no influx of migrating bats from neighbouring countries (also see fig. 6). Norway, however is no direct source fot the SNS. Russia, more specific the western bordering territory, is only incorporated in the model as a source area, although undoubtedly there will be migration from more eastern Russian territory. Others will be countries where there is an influx and outflux of migrating bats (e.g. Denmark). Norway

h) We work on the premise[13] that the majority of the animals from the northern (Scandinavia) and north-eastern European maternity regions (Baltic States, western Poland and western Russia) will hibernate in western Europe in the present case in middle-western Europe.

i) We work on the premise that the number of females born equal the number of males, and that there is an equal survival for both sexes.

j) Males are territorial in the mating season. The ratio between territorial males and satellite males is unknown. It is unclear whether there would be different rations for different zones in the migration direction. There is some evidence that the number of satellite males, not occupying their own territory, is about 4/5 of the population of males (e.g. Lundberg 1989, Lina pers. comm). In the calculation of the flow model this proves to be a factor with a large influence on the outcome. Therefore it is necessary to validate and update this factor. Here we try to compensate for this uncertainty by working with a large uncertainty interval as well as different settings within this interval. In the flow model we calculated with the following variability in this parameter: lower-**central**-upper: 0.2–**2**–5, and a range of different settings: 3–**4**–5, 2–**3**–4, 1-**2-**3 and 0.2-**1.2**-2.2 satellite males per territorial male (pers. com. Peter Lina).

k) We might work on the premise that all young males take part in migration males, as do all adult and young females, where all adult males do not take part in migration. There is, however, evidence that some of the adult males do take part in migration. Boshamer & Bekker (2008) find some adult males

[13] For all premise(s): premise = interpretation of the available knowledge in a way that allows for calculation in the estimation.

on off shore platforms. Lina (pers. comm.) finds adult males with non-swollen buccal glands, together with females and the resident male in bat boxes. It is unclear whether these are 'resident' satellite males, or migrating males. We therefore also work with the assumption that at least a part of the the non-resident male population, the population that not occupies their own mating roost/territory, also migrates.

l) We work on the premise that
- in all geographic regions, more females will take part in migration than males;
- the more south/southwest in Europe we get, the less males take part in migration, the more males stay behind (territorial and/or, hibernation)
- in the autumn, in the northeast of Europe most females will migrate, while more to the south west a larger part will stay behind (hibernate).

m) There are very few data on the fecundity of bats. Available data present J/F ratios of around 0.6 to 0.8 (e.g. O'Shea *et al.* 2011, Schaub *et al.* 2007). We work on the premise that every adult female that is part of the western Europeans migrating population will on average have 0,7 offspring per year. In the flow model we calculated with the following variability in this parameter: (min)0.6-(central)**0.7**-(max)0.8, 0.5-**0.6**–0.7 and 0.4–**0.5**–0.6 juveniles per female.

## Annex 5: Summary of the complex geographic interconnection between distribution, mating/reproduction and migration of the Nathusius' Pipistrelle

From the available knowledge the complex geographic interconnection between distribution, mating/reproduction and migration of the Nathusius' pipistrelle can roughly and tentatively be described as follows (see also Dietz *et al.*, 2011, literature cited in questionnaires and 6.2):

Distribution ranges from Republic of Ireland in the west, to middle Russia and Azerbaijan in the east, and the south of Norway and Finland in the north, to the north of Spain and Greece in the south.

Although knowledge on actual maternity colonies is scarce, maternity colonies are predominantly known, or suspected on the basis of netted females (post lactation phase), in the north eastern part of their range in e.g. the Baltic states, north and northeastern Poland and the West of Russia. In Scandinavia and Northern Germany maternity colonies are rare. In Norway they are not yet confirmed.

In Scotland and Wales no maternity roosts are known. In the Republic of Ireland a few maternity roosts are known but, again larger numbers of roosts are found in Northern Ireland and England.

Males are found throughout the range, with highest densities in the western and southwestern part of the range. E.g. in the Netherlands no maternity colonies are known, whereas high densities of territorial males are registered.

Roughly there is a migration from east/northeast to west/southwest for the autumn migration.

Males occupy territorial mating sites, which are clustered along the flyways of the migrating females in landscapes where females can forage to fuel migration and will seek shelter. While migrating, females will have several stopovers at traditional sites with clusters of territorial males, and will mate several times. Yearling males will participate in the migration and try to establish a territory of their own, but will be part of a floating population for the first few years.

The breeding populations found on the island of Ireland and in England are a startling element in this complex of distribution, mating/reproduction and migration. There is some evidence of migration between UK and the Netherlands.

## Annex 6: Summary feedback on A] flow model

Table 1: overview of response to approach flow model.

| | consent | no comment | no input | information input | quantitative input / comment estimate |
|---|---|---|---|---|---|
| Finland | | 1 | | | |
| Estonia | | | 1 | | |
| Belarus | | | 1 | | |
| Latvia | 1 | | | 1 | |
| Lithuania | | | 1 | | |
| Poland north-western | | | 1 | | |
| Sweden | | 1 | | | |
| Denmark | 1 | | | 1 | |
| Germany northern | 1 | | | 1 | 1 |
| Netherlands | 1 | | | 1 | 1 |
| Belgium | 1 | | | 1 | 1 |
| | | | | | |
| Norway | 1 | | | 1 | 1 |
| | | | | | |
| UK Scotland | 1 | | | 1 | 1 |
| UK Northern Ireland | 1 | | | 1 | 1 |
| UK England/Wales | 1 | | | 1 | 1 |
| UK England/Wales | 1 | | | 1 | 1 |
| RO Ireland | 1 | | | 1 | 1 |
| | | | | | |
| France | | 1 | | | |
| Portugal | 1 | | | | |

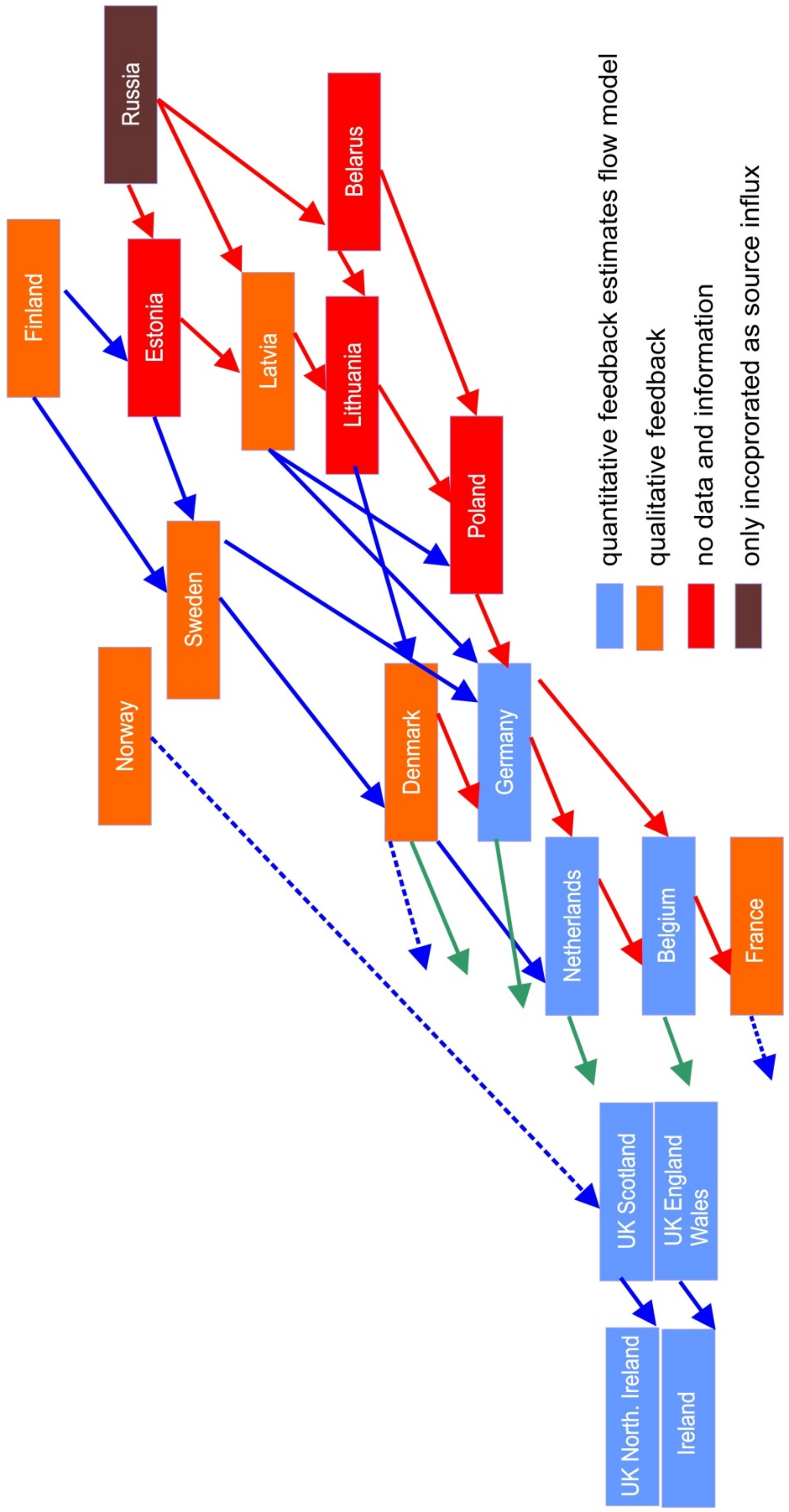



Figure 1: overview feedback flow model (data processed till 20 January 2017)

Table 2: summary feedback flow model

| | FLOW MODEL → | STRUCTURE | VALUES FLOW MODEL |
|---|---|---|---|
| **Germany** | Lothar & Petra Bach | consent | [basic autumn flow direction, also north-south along rivers ][estimated values: rather between minimum and median values][rather 75% males migrating, than 50%][wish for workshop/conference call] |
| | Johanna Hurst | consent | [Ratio male/female 100000 – 4000 is peculiar. Winter population seems more real] |
| **UK** | Kathrine Boughey | no comment | Winter population in UK should be bigger than the summer population as a result of influx |
| | Jon Russ, | consent | [Estimate for North Ireland OK] [estimate females rep Ireland (10000) high considering lack of maternity colonies ROI. Northern Ireland has several known maternity colonies which have been long established but the estimate is only 5000 in comparison]. |
| John Haddow, Susan Swift, Daniel Hargreaves, Fiona Mathews | | general input | |
| **RO Ireland** | Niamh Roche | consent | [Male, female and young in autumn: 3,000-5,000 in Republic of Ireland, 10,000-18,000 in Northern Ireland] [ ROI:NI = approximately 1:3] [ possibility of arriving in NI directly from Scandinavia?] |
| | Tina Aughney | general input | |
| **Scandinavian region** | | | |
| **Norway** | Jeroen van der Kooij | no comment | not able to comment in a quantitative way on estimate input and outcome |
| | Tore Chr Michaelsen | general input | |
| **Sweden** | Johnny de Jong | no comment | not able to comment in a quantitative way on estimate input and outcome |
| **Denmark** | Hans Baagoe + Esben Terp Fjederholt | consent | not able to comment in a quantitative way on estimate input and outcome |
| Ingemar Ahlén, Jan Durinck, Morten Christensen, Morten Elmeros, Thomas W. Johansen and Julie Dahl Møller | | general input | |
| **Finland** | Eeva-Maria Kyheröinen | no comment | |
| **Baltic region** | | | |
| **Latvia** | Gunars Peterson | consent | [info in excel tables] [no published winter records of P. nathusii from Finland, NE Russia, Belorussia, Estonia, Latvia and Lithuania][no knowledge on proportion of sea migrants] |
| **Estonia, Lithuania, Belarus, Poland** | | | Not yet invited to participate an give input |
| **Belgium** | Bob Vandendriessche | consent | [feels that the numbers estimated are to high] |
| | SMITS Quentin | no comment | not able to comment in a quantitative way on estimate input and outcome |
| **France** | Marie-José Dubourg- | no comment | not able to comment in a quantitative way on estimate input and outcome |
| Thomas Le Campion, Dorothee Jouan, Diane Anxionnat | | general input | |
| **Iberic region** | | | |
| **Portugal** | Luisa Rodrigues | consent | not able to comment in a quantitative way on estimate input and outcome |
| **Nederland** | Herman Limpens | consent | |
| | Peter Twisk | consent | [please also consider the spring migration] [ 75:25% Belgium - over sea, should rather be 90:10 %] |
| Jasja Dekker, A-J Haarsma, Jan Boshamer, Theo Douma | | general input | not able to comment in a quantitative way on estimate input and outcome |
| Eric Jansen, Marcel Schillemans | | consent | [males in the Netherlands possibly overestimated] |
| | | | |

## Annex 7: Analysis of the reaction of the prototype estimator (the flow model A]) through using a range of settings for the number of juveniles/female and satellite males/male.

A series of test runs was done, using the model with the current estimates and a range of settings for juvenile/female and satellite males/male. Table 1 illustrates the different settings of J/F that were tested against the different settings of M/SM (lower-**central**-upper).
The test runs result in an overview of preliminary estimates for the potential migrating population over the southern North Sea presented in table 2.

Table 1: illustration of settings J/F tested against settings M/SM

| Satellite males per male | *Juvenile / female* | | |
|---|---|---|---|
| | 0.6 - **0.7** - 0.8 | 0.5 - **0.6** - 0.7 | 0.4 - **0.5** - 0.6 |
| 3 - **4** - 5 | | | |
| 2 - **3** - 4 | | ?-**?**-? | |
| 1 - **2** - 3 | | | |
| 0.2 - **1.2** -2.2 | | | |

These preliminary estimates are also presented in series of histograms, in linear and logarithmic scales, for males, females and juveniles, and totals, for the different juvenile per female ratios, and satellite males per male (see annex VIII).

Table 2: Overview of 'preliminary outcomes of the flow model (representing the 'estimate for the migrating population on the southern North Sea') for different settings for J/F and SM/M. Status 2017.

| | ← bandwidth → | | | ← bandwidth → | | | ← bandwidth → | | | ← bandwidth → | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| juv/female 0.6 - **0.7** - 0.8 | *male low* | ***male*** | *male up* | *fem low* | ***female*** | *fem up* | *Juv low* | ***Juv*** | *Juv up* | *tot low* | ***tot*** | *tot up* |
| satellite 3 - **4** - 5 | 267 | **15.525** | 163.504 | 43 | **19.226** | 521.399 | 26 | **13.458** | 417.119 | 336 | **48.209** | 1.102.022 |
| satellite 2 - **3** - 4 | 200 | **12.477** | 139.066 | | | | | | | 269 | **45.161** | 1.077.584 |
| satellite 1 - **2** - 3 | 134 | **9.428** | 114.628 | | | | | | | 203 | **42.112** | 1.053.146 |
| satelite 0.2 - **1.2** -2.2 | 80 | **6.989** | 95.077 | | | | | | | 149 | **39.673** | 1.033.595 |
| juv/female 0.5 - **0.6** - 0.7 | *male low* | ***male*** | *male up* | *fem low* | ***female*** | *fem up* | *Juv low* | ***Juv*** | *Juv up* | *tot low* | ***tot*** | *tot up* |
| satellite 3 - **4** - 5 | 267 | **15.525** | 163.504 | 43 | **19.226** | 521.399 | 22 | **11.536** | 364.979 | 332 | **46.287** | 1.049.882 |
| satellite 2 - **3** - 4 | 267 | **12.477** | 139.066 | | | | | | | 332 | **43.239** | 1.025.444 |
| satellite 1 - **2** - 3 | 134 | **9.428** | 114.628 | | | | | | | 199 | **40.190** | 1.001.006 |
| satelite 0.2 - **1.2** -2.2 | 80 | **6.989** | 95.077 | | | | | | | 145 | **37.751** | 981.455 |
| juv/female 0.4 - **0.5** - 0.6 | *male low* | ***male*** | *male up* | *fem low* | ***female*** | *fem up* | *Juv low* | ***Juv*** | *Juv up* | *tot low* | ***tot*** | *tot up* |
| satellite 3 - **4** - 5 | 267 | **15.525** | 163.504 | 43 | **19.226** | 521.399 | 17 | **9.613** | 312.839 | 327 | **44.364** | 997.742 |
| satellite 2 - **3** - 4 | 200 | **12.477** | 139.066 | | | | | | | 260 | **41.316** | 973.304 |
| satellite 1 - **2** - 3 | 134 | **9.428** | 114.628 | | | | | | | 194 | **38.267** | 948.866 |
| satelite 0.2 - **1.2** -2.2 | 80 | **6.989** | 95.077 | | | | | | | 140 | **35.828** | 929.315 |

| Min/max values tested settings | ← bandwidth → | | | ← bandwidth → | | | ← bandwidth → | | | ← bandwidth → | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| juv/female 0.4 - **0.6** - 0.8 | *male low* | ***male*** | *male up* | *fem low* | ***female*** | *fem up* | *Juv low* | ***Juv*** | *Juv up* | *tot low* | ***tot*** | *tot up* |
| satellite 0,2 – 2 - 5 | **80** | 9.428 | **163.504** | **43** | 19.226 | **521.399** | **17** | 11.536 | **417.119** | **140** | 40.190 | **1.102.022** |

Table 2 allows us to interpret minimum and maximum values and bandwidths resulting from the different settings for J/F and SM/M as were given in the estimate table 8 in paragraph 3.3).

The outcome or estimate in table 8, for males is roughly between 7.000 and 15.500, with 80 as lowest 'lower', and 160.000 as highest 'upper'[14].

For females this is roughly 20.000, with 40 as lowest 'lowest', and approx. 550.000 as highest 'upper'.

For juveniles the estimated number oscillates between approx. 9.000 and 14.000, with approx. 20 as minimum 'lowest', and approx. 400.000 as maximum 'upper'.

The number of satellite males, with settings from 0.2-**1.2**-2.2 to 3-**4**-5, affects the size of the population of males migrating across the southern North Sea (central estimate) with a factor of approximately 2 (table 2 and figures in annex VIII). This illustrates the need to investigate the number of satellite males/male in general and for the different landscapes and regions in Europe.

The juveniles/female ratio, with settings from 0.4-**0.5**-0.6 to 0.6-**0.7**-0.8, effects the size of the population of juveniles migrating across the southern North Sea with a factor of approximately 1.5 (table 2 and figures in annex VIII). This

[14] Values from table 8 are rounded off: 'highest and lowest value' for the central estimate are repeated with the 'lowest value for the lower value of the estimate' and the 'highest value for the upper value of the estimate'.

illustrates the need to investigate the number of juveniles/female in general and for the different landscapes and regions in Europe.

In a next step, data presented in table 3, are used to produce an overview of the bandwidth factors of estimations of the migrating population of the Nathusius' pipistrelle over the southern North Sea. The 'bandwidth factor' indicates the factor that the central number is higher than the lower limit, the factor by which the upper limit is higher than the central number , and by which factor the upper limit is higher than lower limit.

Table 3: overview of **bandwidth factors** of the output of the test runs for estimations of the migrating population of the Nathusius' pipistrelle over the southern North Sea, status January 2017 (see excel table, sheet estimates overview rearranged). Presented are bandwidth factors which inform how many times, upper is higher than lower, upper is higher than central and central is higher than lower.

| **Upper/Lower = U/L factor = factor upper is higher than lower** | | | | | |
|---|---|---|---|---|---|
| | *lower* | ←← Bandwidth factor →→ | | | *upper* |
| | | | | | |
| | *lower* | | ***central*** | | *upper* |
| **M** | | | <<< | | 600 – 1.200 |
| **F** | | | <<< | | 1200 |
| **J** | | | <<< | | 16.000 – 18.500 |
| | | | | | |
| **T** | | | <<< | | 3.000 – 7.000 |

| | | | | | |
|---|---|---|---|---|---|
| | | | **Upper/Central = U/C = factor upper is higher than central** | | |
| | | | ←← Bandwidth factor →→ | | |
| | **Central/Lower = C/L = factor central is higher than lower** | | | | |
| | ←← Bandwidth factor →→ | | | | |
| | | | | | |
| | *lower* | | ***central*** | | *upper* |
| **M** | | <<< | 60 - 90 | <<< | 10 - 14 |
| **F** | | <<< | 450 | <<< | 27 |
| **J** | | <<< | 520 - 565 | <<< | 30 - 33 |
| | | | | | |
| **T** | | <<< | 130 and 270 | <<< | 22 - 26 |

For the preliminary estimations of the migrating population of the Nathusius' pipistrelle over the southern North Sea, the bandwidth between upper and lower for totals is relatively large. The observed bandwidth factors between 3.000 and 7.000 (upper between 3.000 and 7.000 times higher than lower) reflect the uncertainty in estimation of regional basic data.

Factors for males and females are of the same order, around 1.200, with a variation between 600 and 1.200 for males, as a result of different settings for satellite males. The factors for juveniles are a magnitude higher as a result of the juvenile/female ratio settings, which work in the direction of enlarging the differences.

For total numbers, the factors between the lower limit and central number (C/L) and the central number and upper limit (U/C) estimates, are [130 – 270] and [22 – 26]. For males, females and juveniles they are [60-90] and [10-14], [450] and [27] and [20-565] and [30-33] respectively.

The difference in magnitude between C/L and U/C is a result of consequently multiplying with 'lower values' of all estimates and factors (e.g. %migrating, J/F ratio[15], satellite males per male et cetera) for the 'lower estimate', and with the higher values for the 'higher estimate' (table 4).

Table 4: example of calculation

| | | factors | | | | | | e.g. estimated pop. size | | factors --> result |
|---|---|---|---|---|---|---|---|---|---|---|
| upper | U | 0,9 | x | 0,8 | x | 0,5 | x | 4000 | = | 1440 |
| central | C | 0,7 | x | 0,6 | x | 0,3 | x | 400 | = | 50,4 |
| lower | L | 0,5 | x | 0,4 | x | 0,1 | x | 40 | = | 0,8 |
| | | | | | | | | | | |
| | | Bandwidth factors | | | | | U/L | 100 | | 1800 |
| | | | | | | | U/C | 10 | | 28,57 |
| | | | | | | | C/L | 10 | | 63 |

The difference in magnitude between males versus females and juveniles is a result of the differences between the defined %'s of migrating females and males. The difference between juveniles and female is again related to the different settings for J/F ratio.

[15] J/F ratio = Juvenile/Female ratio

## Annex 8: Preliminary estimates for migrating Nathusius' pipistrelle over the southern North Sea - histograms of test runs status January 2017

The preliminary estimates, for the range of settings depicted in table 1, annex VII, are presented in series of histograms, in linear and logarithmic scales, for males, females and juveniles, and totals, for the different juvenile per female ratios, and satellite males per male.

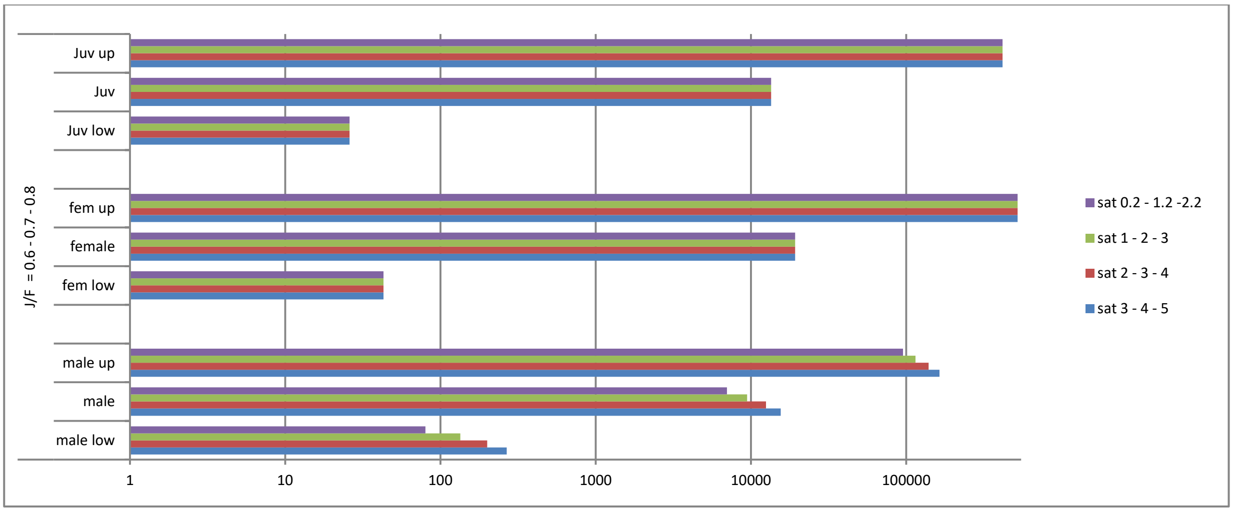



Figure 1: outcome test run J/F 0.6-0.7-0.8 logarithmic scale

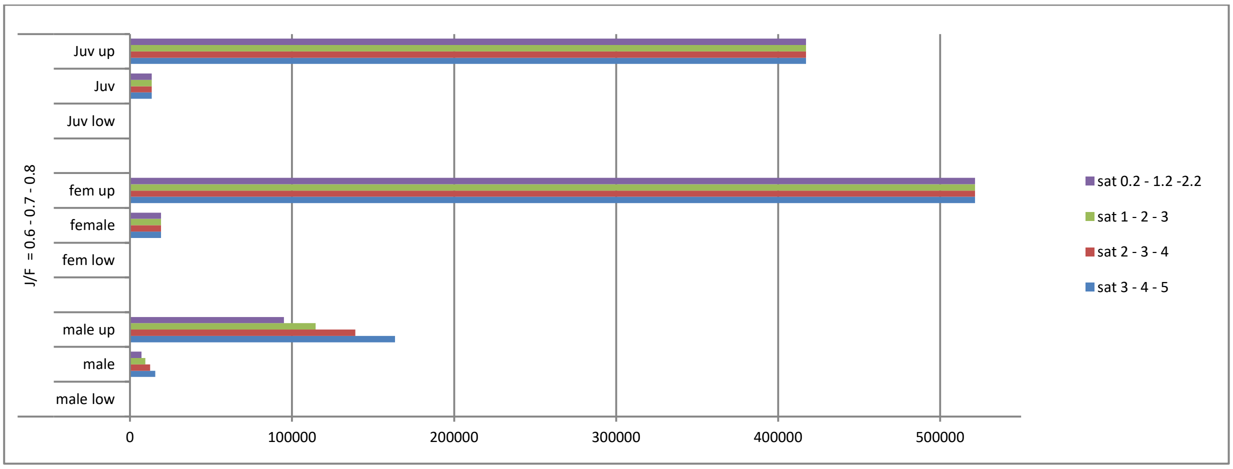



Figure 2: outcome test run J/F 0.6-0.7-0.8 linear scale

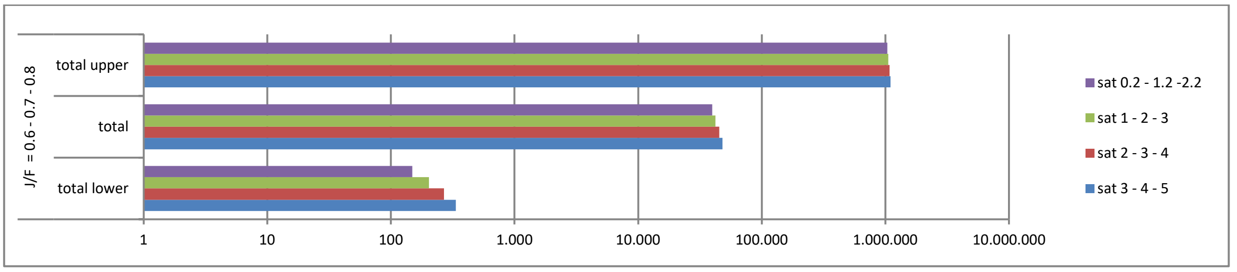



Figure 3: outcome test run J/F 0.6-0.7-0.8, totals, logarithmic scale

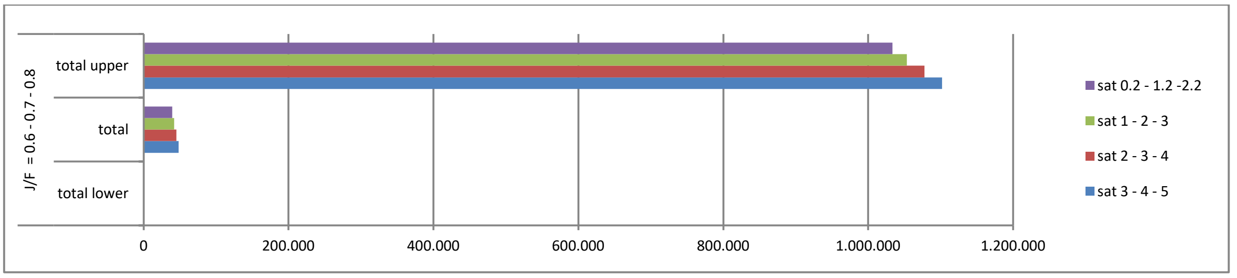



Figure 4: outcome test run J/F 0.6-0.7-0.8, totals, linear scale

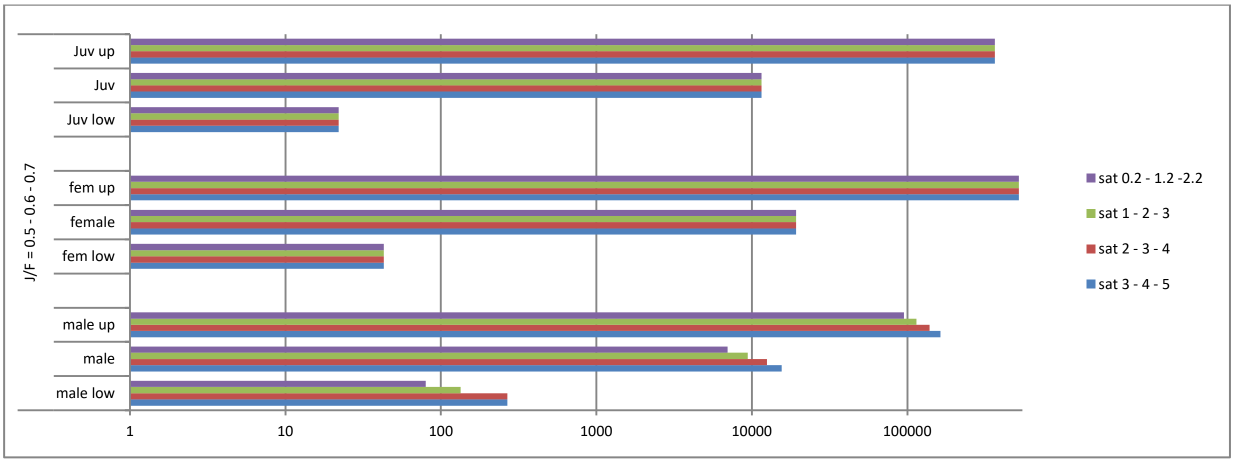



Figure 5: outcome test run J/F 0.5-0.6-0.7, logarithmic scale.

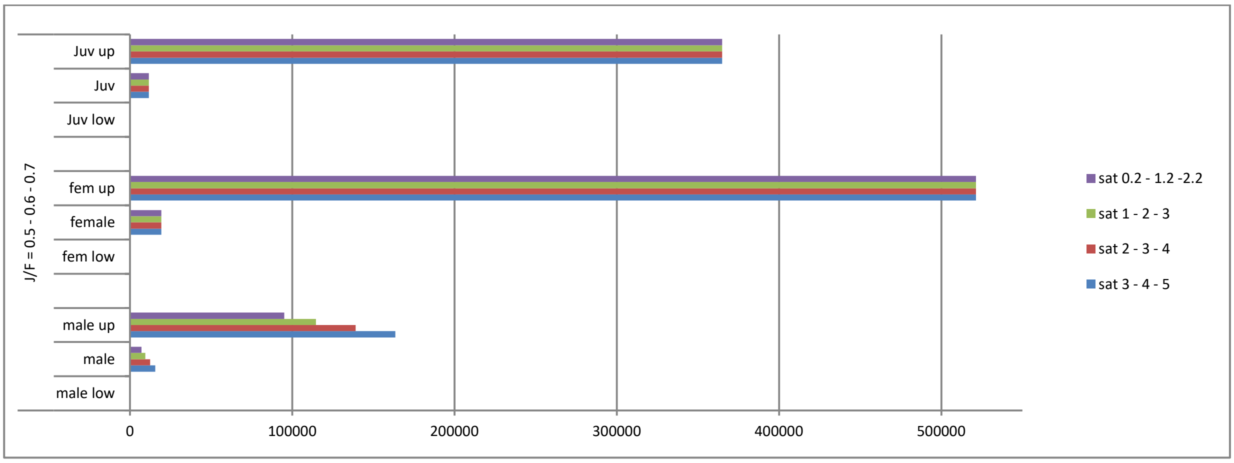



Figure 6: outcome test run J/F 0.5-0.6-0.7, linear scale.

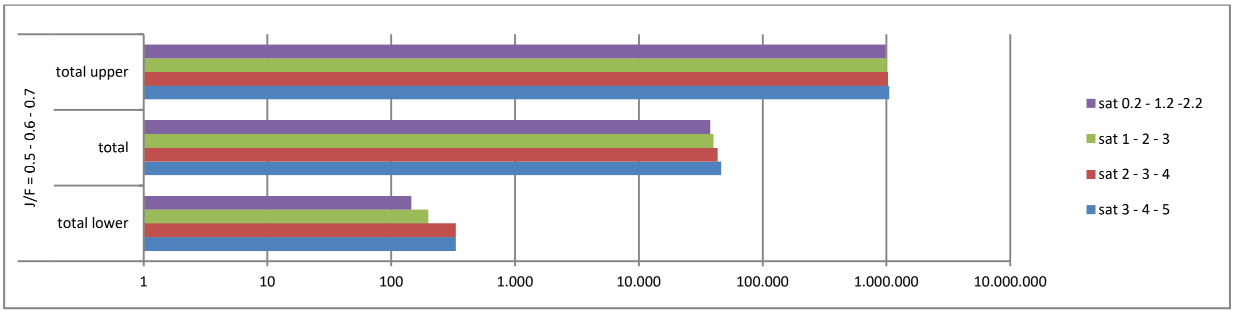



Figure 7: outcome test run J/F 0.5-0.6-0.7, totals, logarithmic scale.

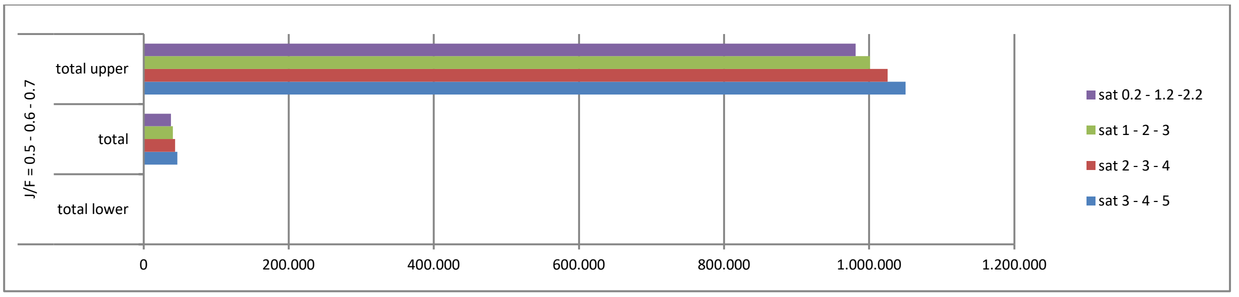



Figure 8:outcome test run J/F 0.5-0.6-0.7, totals, linear scale.

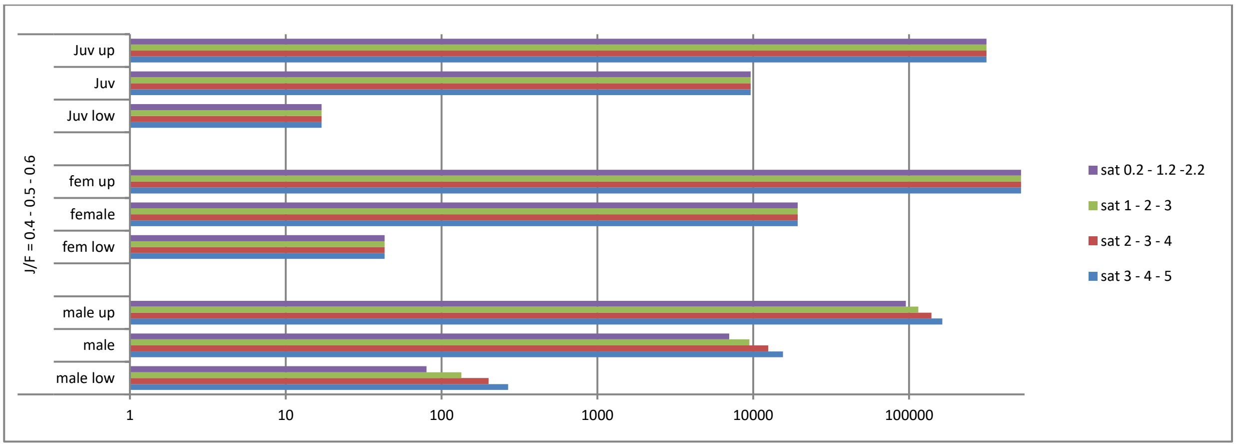



Figure 9: outcome test run J/F 0.4-0.5-0.6, logarithmic scale.

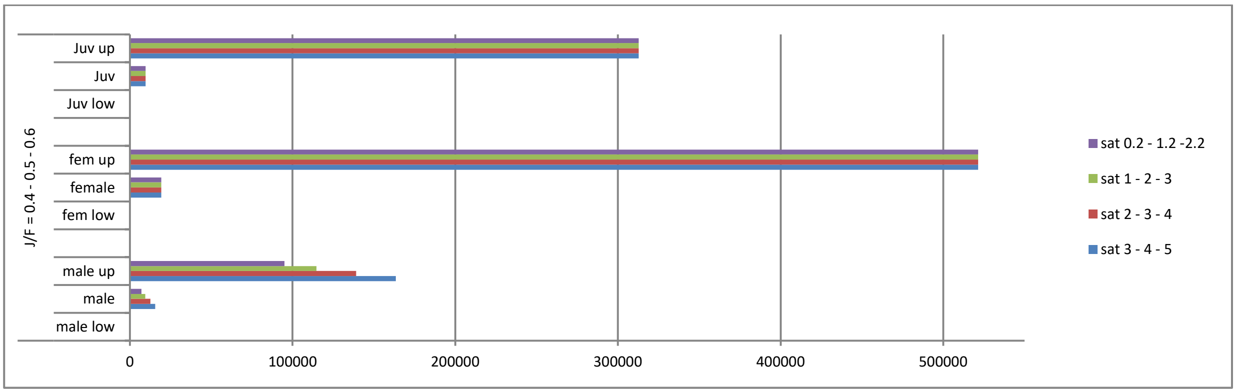



Figure 10: outcome test run J/F 0.4-0.5-0.6, linear scale.

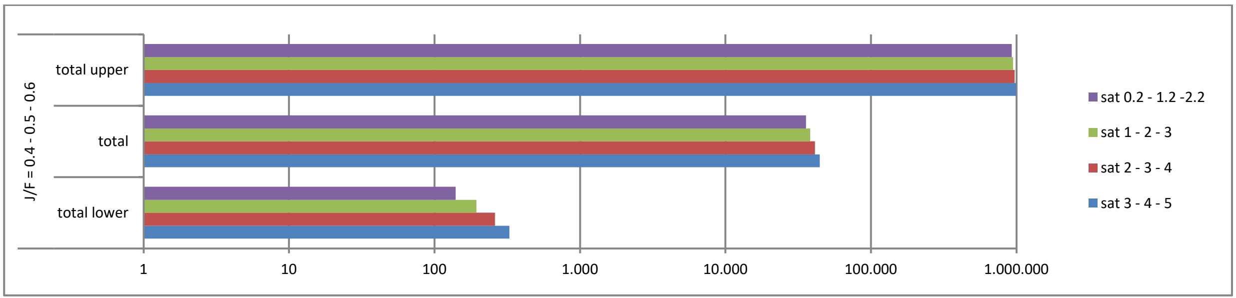



Figure 11: outcome test run J/F 0.4-0.5-0.6, totals, logarithmic scale.

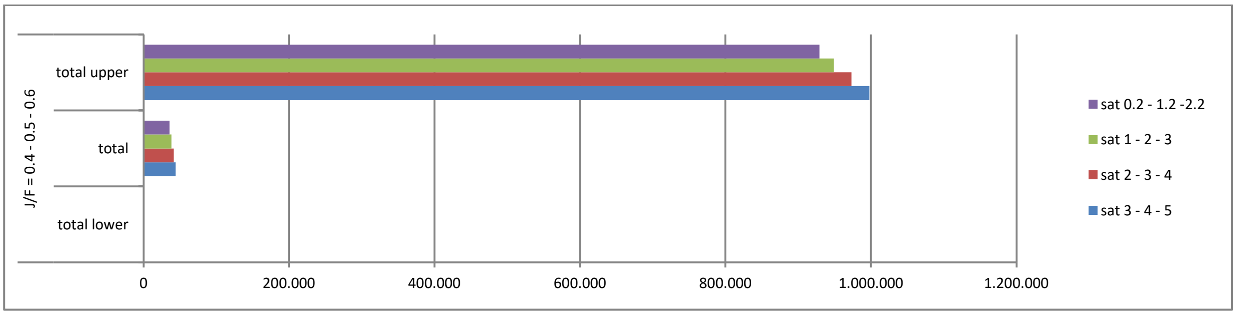



Figure 12: outcome test run J/F 0.4-0.5-0.6, totals, linear scale.