
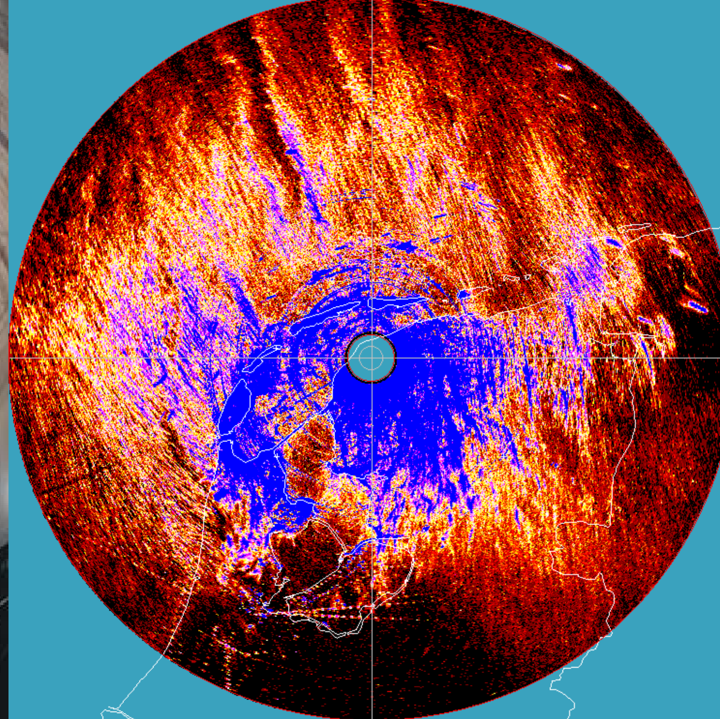

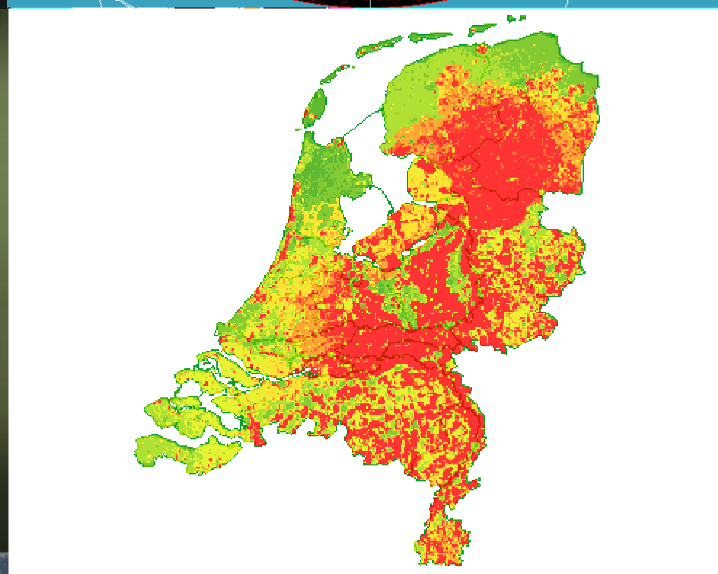

The Netherlands Bird Avoidance Model

NL-BAM final report

May 2006

Universiteit van Amsterdam
Sovon Vogelonderzoek Nederland
Koninklijke Luchtmacht

The Netherlands Bird Avoidance Model (NL-BAM)

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Contributors: Judy Shamoun-Baranes[1], Willem Bouten[1], Henk Sierdsema[2], Jelmer van Belle[3], Hans van Gasteren[3], Emiel van Loon[1]

[1] Computational Biogeography and Physical Geography, IBED, Universiteit van Amsterdam, Nieuwe Achtergracht 166, Amsterdam 1018WV, The Netherlands.

[2] SOVON Dutch Centre for Field Ornithology, Rijksstraatweg 178, 6573 DG Beek-Ubbergen, The Netherlands.

[3] Nature Bureau, Directorate of Operations Royal Netherlands Airforce, POB 20703, 2500 ES Den Haag, The Netherlands

Table of contents

Extended summary

The NL-BAM was developed as a web-based decision support tool to be used by the bird hazard avoidance experts in the ecology unit of the Royal Netherlands Air Force. The NL-BAM will be used together with the ROBIN 4 radar system to provide BirdTAMS, for real time warnings and flight planning and to give an overview of the predicted bird hazards in the Netherlands to air traffic controllers, flight coordinators, squadron leaders and airfield bird control units. The NL-BAM was developed by a multidisciplinary team and through the cooperation of the people from the Institute for Biodiversity and Ecosystem Dynamics (IBED) and the Informatics Institute of the University of Amsterdam, the Royal Netherlands Air Force and SOVON, the Dutch Centre for field Ornithology.

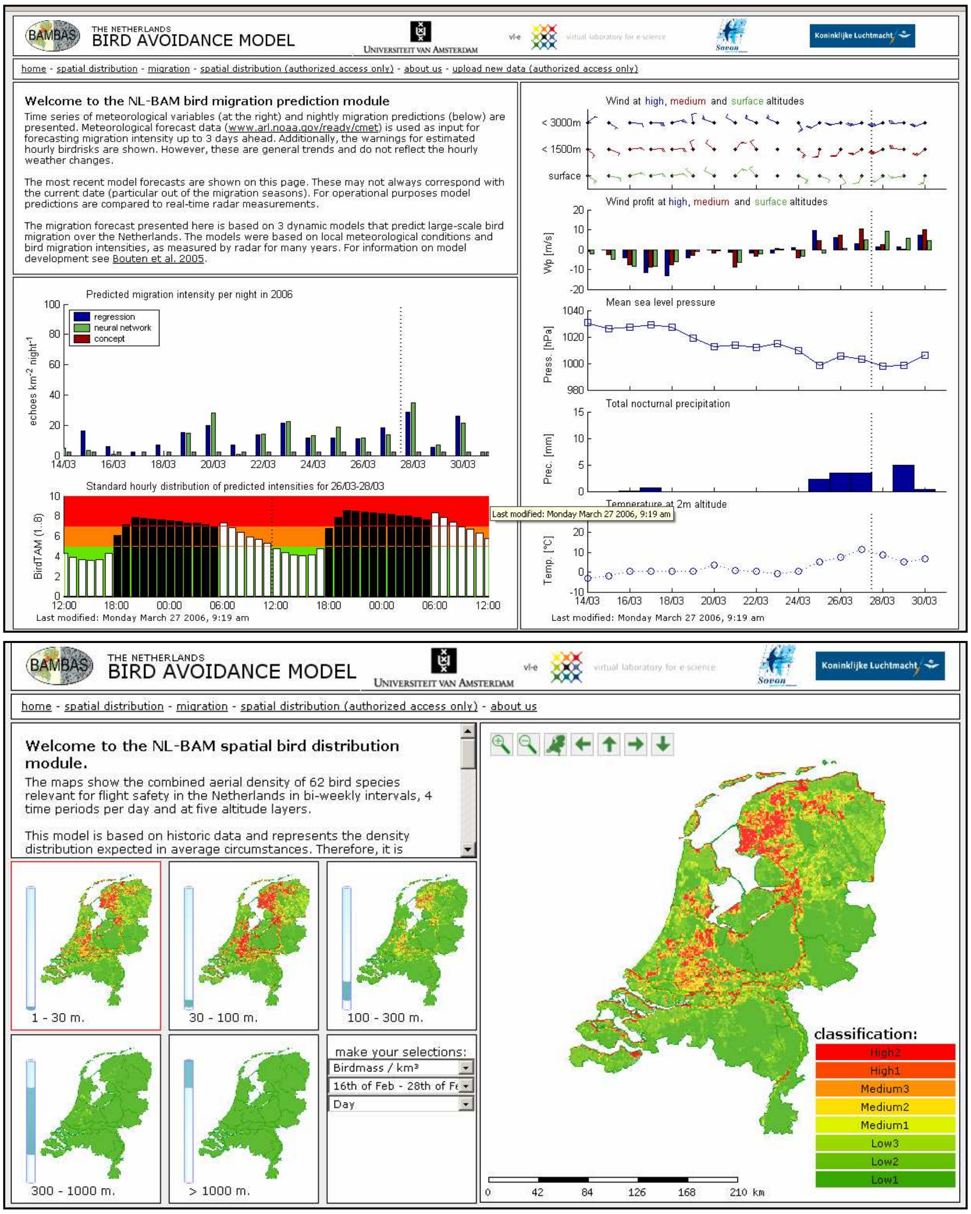
The NL-BAM is accessible to the general public on the Internet at http://ecogrid.sara.nl/bambas. The website and models are divided into two modules, "migration prediction" and "spatial distribution".

The migration module of the NL-BAM is a dynamic model and predicts the density of migrants during the day and at night for 3 consecutive days based on real-time and/or forecasted meteorological data. During the migration season, migration forecasts are updated daily by members of the RNLAF. Predictions are presented in figures on the NL-BAM website. The autumn nocturnal forecasts are based on three data-driven models: a log-linear regression model, a conceptual model and a neural network model. The spring forecasts include a log-linear regression model and a neural network model. Diurnal forecasts are based on nocturnal forecasts by the log-linear relationship between nocturnal and diurnal migration intensities.

The spatial distribution module includes spatial density maps of the 62 bird species selected as most relevant for flight safety in the Netherlands in bi-weekly intervals, four time periods per day and at five altitude layers. This module is based on historic field observations and represents the density distribution expected in average circumstances. The key species were selected based on criteria such as total number of birdstrikes, number of damaging birdstrikes, availability of data, mass, behaviour of birds, expert knowledge on species and conservation importance. The spatial distribution of each species was modelled in relation to environmental conditions using a combination of regression models, spatial statistics and expert knowledge. Furthermore, the altitude distribution of several species of birds was modelled in relation to meteorological conditions. Expert knowledge and additional sources were used to complete information on the altitude distribution, temporal activity

(daily), annual abundance and flight activity. The public access website includes composite maps of mass and separately for number of birds/km^2 for each time of year, time of day and altitude combination (480 combinations). An authorized access page, accessible only by team members, also includes individual maps for each species as well as a summary table including total numbers of the top 10 most abundant species per region for each time of year, time of day, altitude combinations.

Finally, although much has been accomplished in the last few years, it is clear that much more can be still be achieved in the field of bird strike avoidance research. We hope that future projects will emerge and be as productive as this one, if not more.



Screen shots of the NL-BAM migration module (top) and spatial distribution module (bottom).

http://ecogrid.sara.nl/bambas

Introduction

In early 2002, Luit Buurma approached Willem Bouten to discuss potential cooperation between the Royal Netherlands Air Force and the University of Amsterdam to develop a Bird Avoidance Model applying state of the art modelling techniques to provide bird migration predictions. The Development of the Netherlands Bird Avoidance Model (further referred to as the NL-BAM) officially began in September 2002. At that time a research and development team was organized with participants from UvA (Universiteit van Amsterdam), Sovon (Dutch Centre for field ornithology) and the RNLAF (Royal Netherlands Air Force). During the years, team members have changed a bit but the core group of people involved in research and development or mainly discussions were as follows (with management team member in bold):

The research and development team

Universiteit van Amsterdam

Willem Bouten, Judy Shamoun-Baranes, Floris Sluiter, Emiel van Loon,

Additional support from Harry Seijmonsbergen and Guido van Reenen

Sovon

Ruud Foppen, Henk Sierdsema

Royal Netherlands Air Force

Luit Buurma, Arie Dekker, Albert de Hoon, Jelmer van Belle, Hans van Gasteren

During the last few months several working groups were established with different responsibilities and closer contact between participants as follows:

Migration modeling working group

Jelmer van Belle, Willem Bouten, Hans van Gasteren, Judy Shamoun-Baranes

Spatial modeling working group

Judy Shamoun-Baranes, Henk Siersema, Hans van Gasteren, Emiel van Loon

Website working group

Floris Sluiter, Judy Shamoun-Baranes, Willem Bouten

The following report describes how the different models developed during the last 3 years have been integrated, together with expert knowledge and additional data sources to create the NL-BAM launched on the Internet in early spring 2006. For the most part, modeling techniques are covered in a series of scientific publications and internal reports that are an integral part of this report and added as appendices. For us, the developers, this report is not the end of the BAM project but hopefully the beginning of future joint initiatives.

NL-BAM design

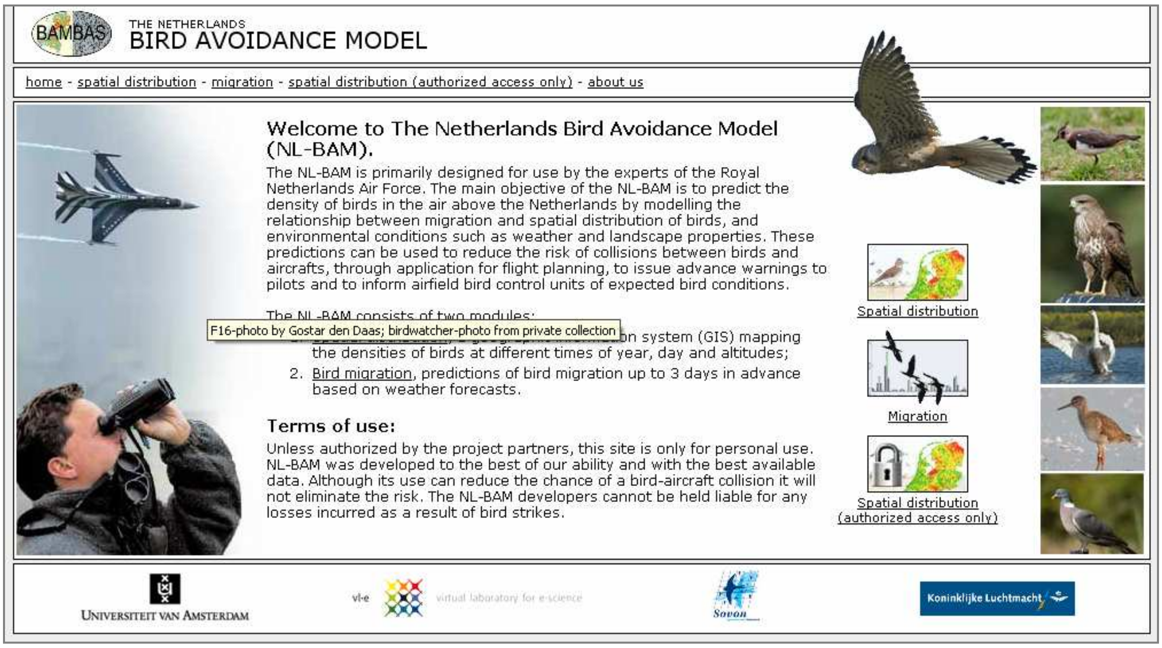
The NL-BAM was developed as a web-based decision support tool to be used, at least initially, by the bird hazard avoidance experts in the ecology unit of the Royal Netherlands Air Force (at the time of this report: Arie Dekker, Jelmer van Belle and Hans van Gasteren). The NL-BAM will be used together with the ROBIN 4 radar system to provide BirdTAMS, for real time warnings and flight planning and to give an overview of the predicted bird hazards in the Netherlands to air traffic controllers, flight coordinators, squadron leaders and airfield bird control units.

For maximum efficiency the NL-BAM is divided into two modules, "migration prediction" and "spatial distribution". During the migration season, migration forecasts are updated daily in the migration prediction module by members of the RNLAF. Due to an exclusive agreement between the three partners, the "spatial distribution" module has two formats, an open access format and an authorized access format. The public access spatial distribution module include composite maps for total number of birds per grid cell (number/km^2) as well as total mass per grid cell (kg/km^2). In addition to these maps, the authorized access spatial distribution module includes the species specific maps for all time of day, time of year and altitude combinations. The authorized access page also includes a summary table for each time/date/altitude combination including the top 10 species (total number of birds) in each of three regions defined as "high Netherlands", "low Netherlands" and "Riverine area". The summary table has a dynamic link to each of the relevant maps, by clicking on a species name in the table, the relevant map automatically appears. By clicking on a new time/date/altitude combination, the table is automatically updated.

UMN/MapServer open source software (http://mapserver.gis.umn.edu/) is used to facilitate the visualization and access of hazard maps stored in postgreSQL (http://www.postgresql.org/) an open source spatial database. Using MapServer's GIS functionality, the user can zoom in and out of maps as well as pan east, west, north and south. In the following report, each of these modules will be described separately.

The NL-BAM website is hosted at a server in the super-computing centre SARA, providing around the clock professional backup and maintenance services. The URL is http://ecogrid.sara.nl/bambas .

NL-BAM homepage screenshot (http://ecogrid.sara.nl/bambas)



The Migration Prediction Module

1. Introduction

The migration module of the NL-BAM is a dynamic model and predicts the density of migrants during the day and at night for 3 consecutive days based on real-time and/or forecasted meteorological information. Predictions are presented on the Internet as graphs.

The MATLAB program *BAM_migr_prediction.m* forecasts the total nocturnal and diurnal migration densities over the northeast of the Netherlands. Both the nocturnal and diurnal forecasts are translated to hourly BirdTAM values, as used by the RNLAF, using the mean hourly pattern of migration intensities. The nocturnal forecasts are based on three data-driven models: a log-linear regression model, a conceptual model and a neural network model. The nocturnal forecasts are used for diurnal forecasts by the log-linear relationship between nocturnal and diurnal migration intensities. For a description of the integration of these models see Appendix B1 (Bouten *et al.* 2005).

All nocturnal density models have been developed and tested for nocturnal spring and autumn bird migration and meteorological measurements over the northeast of the Netherlands in 2001, 2002 and 2003. For a detailed description of the in-and output variables used for these models see Appendix B2 (Van Belle *et al.* in preparation).

2. Required data

All models forecast nocturnal bird migration from meteorological forecast data and a baseline of daily nocturnal migration intensities. The forecast data location for the meteorological input variables is Groningen/Eelde, NL (53°13'N 6°58'E, WMO code EHGG). The models require 3-hourly forecasts for rain, sea level pressure and temperature (surface level), and for wind speeds and directions (from surface level up to 850 hPa, app. 1500m altitude). The meteorological forecast data can be obtained from the NOAA website (http://www.arl.noaa.gov/ready/cmet.html).

The baseline variable is provided by the MATLAB data file *baseline.mat*. This baseline is based on radar measurements of 1989-1995 in the same measurement window, on the same radar as the later data used to develop the migration forecasts models. The baseline is a daily running mean of total nocturnal migration intensities over 21 days for these 7 years. All observed directions are included in the baseline. Because of changes in the interface between the radar and the bird intensity measurement program, absolute numbers are slightly lower than in the data used for model calibration.

3. Overview of the BAM_migr_prediction MATLAB script

The MATLAB script *BAM_migr_prediction.m* predicts nocturnal migration densities for the current date and two nights ahead. Both the input variables and the resulting nocturnal forecasts are saved into one three-dimensional array, *MainArchive.mat*. In this array, for each date (1st dimension), for all input- and output variables (2nd dimension) forecasts for the current date and two nights ahead (3rd dimension) are saved. Due to this redundant set-up, missing meteorological forecast data can be replaced by earlier forecasts of the same day.

First, the downloaded meteorological forecasts for the current date are read and saved into the MainArchive by the script BAM_migr_readmeteo.m . The original text files are saved to the subdirectory .../backup.

The nocturnal migration forecasts are produced and saved in the MainArchive.mat by BAM_migr_noctprediction.m. For both spring and autumn, three different forecasts are produced: from a log-linear regression model, from a conceptual regression model and from the mean of a set of neural network models. All forecast models are based on meteorological and radar bird intensity measurements in 2001, 2002 and 2003.

BAM_migr_hrtransform.m extrapolates the nocturnal migration intensity forecasts to diurnal forecasts using the log-linear regression coefficient between nocturnal forecasts and diurnal measurements for 2001-2003. The forecasted total nocturnal and diurnal intensities are back-transformed to hourly intensities on a log-linear scale of 1-8, according to the BirdTAM values used by the RNLAF. This hourly interpolation is based on the mean nocturnal and diurnal patterns of migration intensities, as observed in the 1989-1995 and 2001-2003 data sets. For a description on the hourly pattern, see paragraph 4.1. This is not a robust prediction, since changes in weather during the night or day are not taken into account.

The weather forecasts are shown and saved into a png-figure by BAM_migr_plotmeteo.m. The forecasted nocturnal migration intensities and the hourly transformations are plotted into one figure by BAM_migr_plotpredictions.m and BAM_migr_plothrpred.m respectively.

4. Models

For a detailed description of the input- and output data for all models, see Appendix B2 (Van Belle *et al* in preparation) on the validation and calibration of autumn regression models. For a quick overview of the output variables in the models see Table 1.

Table 1. Overview of the variables used in the BAM_migration_prediction models.

Variable	*Description*	*units*
I_b	baseline nocturnal migration intensity	echoes/night
W_p	wind profit (m/s) according to the median bird speed (12 m/s) and the median bird flight direction (47° in spring, 223° in autumn)	m/s
R_{dur}	relative nocturnal duration of rainfall	0-1
R_{noct}	total nocturnal rainfall	mm
P	Barometric pressure at 23:00Z	hPa
ΔP	barometric pressure difference between each day and its previous day	hPa
T	ground level temperature at 23:00Z	°C

4.1 Hourly patterns of migration intensities

Hourly patterns of migration intensities were required for two reasons: (1) to improve the data set that was used for model development and (2) to back-transform forecasted total nocturnal migration intensities to hourly nocturnal and diurnal migration intensities.

First, models were developed for summated nocturnal intensities but for several nights, one or more of hourly measurements were missing. For all nights with >= 50% of the hourly measurements available, intensities for missing hours were interpolated by the mean hourly pattern of migration intensities and the measured migration intensity for that night.

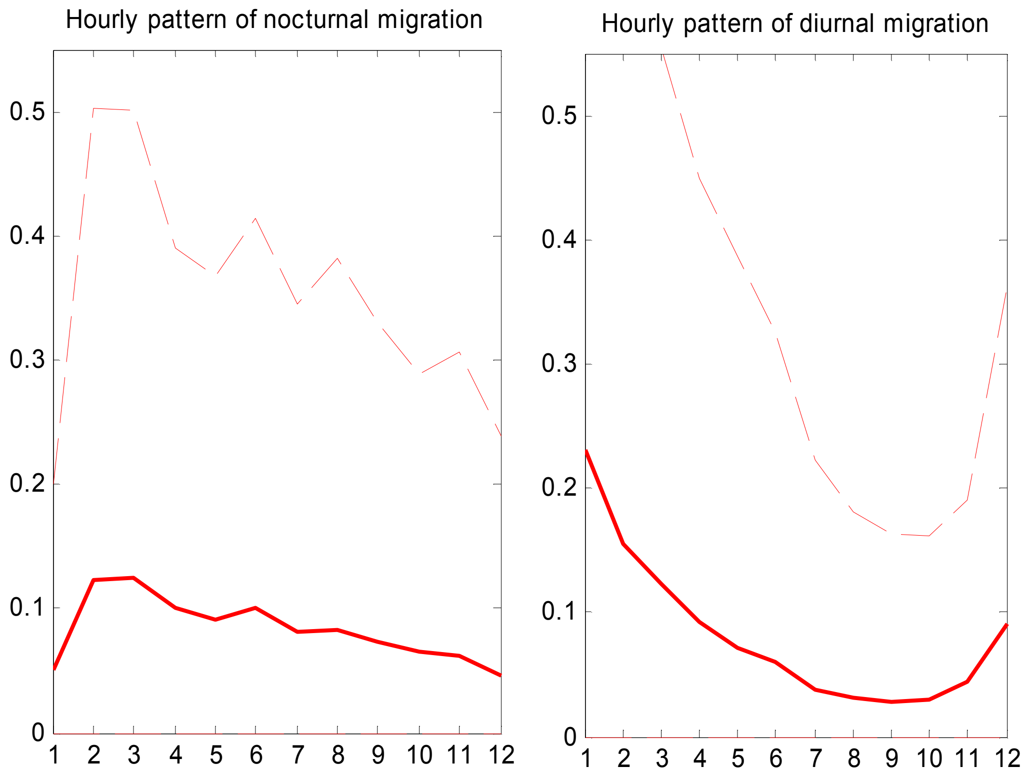


Figure 1. Mean and 90% intervals of 12-hourly standardized relative migration intensities for nocturnal (left) and diurnal (right) migration.

The hourly patterns of migration intensities were calculated from the radar measurements of 1989-1995 and 2001-2003, both for nocturnal and diurnal migration. All hours with total migration intensity > 0 were used. All measurement hours were indexed as if they belonged to a night or day of 12-hour length. For example in a short summer night, lasting only 6 hours, the hours would be indexed as hours 1, 3, 5, 7, 9, 11. Conversely for a long winter night lasting 16 hours, the hours would be indexed as hours 1, 2, 2, 3, 4, 5, 6, 6, 7, 8, 8, 9, 10, 10, 11, 12. The lengths of the nights and days were determined by sunrise and sunset at Eelde/Groningen, NL. For each of the 12 index hours, the mean measured migration intensity was calculated. For the standard patterns, these values were rescaled so that the total sum of the hourly mean intensities equalled 1 (figure 1).

Secondly, these standard patterns were used for the back-transformation of nocturnal forecasted intensities to hourly values. For diurnal hourly back-transformations a diurnal standard pattern was calculated in the same way as the nocturnal standard pattern.

Additionally for both nocturnal and diurnal back-transformations, a 0th and a 13th hour were occasionally necessary. These were obtained by linear extrapolation.

4.2 Regression models

The regression models were calculated for the natural logarithms of the migration intensities to fulfil to the normality requirements for regression models.

Selection of input variables for these log-linear regression models was based on calibration by data sets of two years, and validation by the third year, for all three combinations of two years. Because of the similarities between the three models, and the critical size of the data set, we decided to calibrate the final model, with the selected input variables, on all three years. This final model was, therefore, not validated.

The spring model forecasts the migration intensity from the migration baseline, the wind profit and the proportion of nocturnal hours with rain (values between 0 and 1):

$$\ln(Y_{spring} + 1) = -0.132 + 1.11 \cdot \ln(I_b) + 0.149 \cdot W_p - 1.36 \cdot R_{dur}$$

The autumn model forecasts the migration intensity from the migration baseline, wind profit, one-day barometric pressure difference and the proportion of nocturnal hours with rain:

$$\ln(Y_{autumn} + 1) = 1.24 + 0.84 \cdot \ln(I_b) + 0.154 \cdot W_p + 0.043 \cdot \Delta P - 0.79 \cdot R_{dur}$$

4.3 Conceptual models

Similarly to the linear regression models, the conceptual models were based on logarithmic migration intensities. The input variables were selected and constructed based on the concepts of migration rather than on stepwise regression techniques. Thus, in addition to the migration baseline and the wind profit, an adverse-weather variable and a bird accumulation variable were introduced. The adverse-weather variable diminishes the contribution of the baseline to the forecast if negative wind profits and/or nocturnal rainfall exceed certain thresholds. The bird accumulation variable increases the forecasted value if previous weather conditions may have prevented the birds from flying. The contribution of the bird accumulation variable to the forecast is increased if negative wind profits exceed a threshold. The thresholds and the coefficients of the adverse weather variable and the bird accumulation variable have been optimized using the SCEM algorithm (Vrugt & Bouten 2003, see Appendix B3: Van Gasteren 2005).

in formula:

$$\ln(Y_{autumn}+1)=0.20\cdot W_p+1.21\cdot\ln(I_b+1)\cdot\varphi_{rw}+4.57\cdot\ln(I_{acc}+\varphi_w+1)$$

where φ_{rw} indicates the adverse weather variable based on rainfall and negative wind profit:

$$\varphi_{rw}=\begin{cases}0.62 & \text{If } R_{noct}>=7.57mm \mid W_p<-7.69m/s\\ 1 & \phantom{\text{If }} R_{noct}<7.57mm\cap W_p>=-7.69m/s\end{cases}$$

and the accumulating effect of adverse wind on potential migration intensity I_{acc} is modelled as

$$I^t_{acc}=\begin{cases}0.67\cdot I^{t-1}_{acc} & \text{If } I^{t-1}_{acc}>0\\ 0 & \phantom{\text{If }} I^{t-1}_{acc}=0 \mid I^{t-1}_{acc}=NaN\end{cases}$$

for which the adverse wind factor φ_w is defined as

$$\varphi_w=\begin{cases}0.33 & \text{If } W_p<-7.69m/s\\ 0 & \phantom{\text{If }} W_p>=-7.69m/s\end{cases}$$

This conceptual model is only available for forecast of autumn migration.

Similarly to the regression models, selection of input variables for the conceptual regression models was based on calibration on data sets of two years, and validation by the third year, for all three combinations of two years.

4.4 Neural Network models

The neural network models were developed using the open-source MATLAB toolbox "Netlab" (see http://www.ncrg.aston.ac.uk.netlab/index.php). Models were trained by forward propagation using "Scaled conjugate gradient" (SCG) optimization. To prevent overtraining, the maximum number of input variables was limited to four and the maximum number of hidden nodes was limited to three. For spring, the selected input variables were the baseline migration intensity I_b, the wind profit W_p, relative nocturnal rain duration R_{dur} and surface level temperature T . For autumn, the selected input variables were the baseline migration intensity I_b, the wind profit W_p, relative nocturnal rain duration R_{dur} and the daily barometric pressure difference ΔP .

For both spring and autumn, 1000 neural nets were calibrated and validated for randomized subsets of respectively 2/3 and 1/3 of the total data set. The neural nets with the highest R^2 in the validation tests were used for the forecast models. For spring the threshold R^2 was 0.50, for autumn 0.65, so that approximately 5% of the models remained.

In the preliminary test phase of autumn 2005, 4 of the neural nets yielded extremely high forecasts (migration intensities >>10.000) at 3-5 nights: these nets were deleted from the forecast models. The final forecast is calculated as the mean of the remaining neural net forecasts.

4.5 Diurnal migration intensity

Forecasts of diurnal migration are calculated from the log-linear relationship between the nocturnal forecasts and the diurnal measurements in spring and autumn 2001-2003.

For spring, the relationship is

$\ln(Y_{day}+1) = 0.38 \cdot \ln(Y_{noct}+1)$, with an RMSE of 0.68 and a R^2 of 0.32

For autumn, this relationship is

$\ln(Y_{day}+1) = 0.44 \cdot \ln(Y_{noct}+1)$, with an RMSE of 0.7 and a R^2 of 0.26

5. Program Manual

Production of bird migration intensity forecasts includes:
- Collection of the meteorological data from the Internet
- Running the MATLAB scripts
- Uploading the resulting graphs to the BAMBAS Internet page
- Uploading the predictions to a centrally stored archive

5.1 Notation of window titles, commands etc:

- Window titles and accompanying texts are written between quotes: “ ”
- Titles of buttons are given in *italic.*

- Text and commands to be entered are given between straight brackets: < >. These brackets should not be typed!
- <ENTER> and <ESC> relate to the keys on your keyboard.

5.2 Collection of the meteorological data

- go to a computer with access to the internet, open an internet browser and open the NOAA current meteorology site: http://www.arl.noaa.gov/ready/cmet.html
- Enter the WMO code voor Eelde/Groningen: <EHGG>.
- Click *continue* end you are taken to the site with "Ready products for location: Groningen/Eelde –NL". This is where you will collect forecasts on wind up to high altitudes (WINDGRAM) and general meteorological variables (METEOGRAM).
- Select the "GFS model (0-84h, 3hrly, global)" from the list next to "METEOGRAM",. Click *Go* if you are not automatically taken to the next page.
- You have reached the "GFS Meteogram" site. Leave everything as is, enter the given "access code" at the right bottom corner of the page and click *Get Meteogram*.
- Now you are taken to the "GFS Meteogram for EHGG" site, with rain intensity in the upper graph, and several variables for temperature and barometric pressure below.
- At the bottom of the page is a link to the *text results*. Click it with your right mouse button, select "Save target as" (in Dutch:"Doel opslaan als") and save the text file. Use the format YYYYMMDD_METGRAM.TXT to determine the filename (for example 20060214_METGRAM.TXT for the meteogram of valentine's day 2006)
- After saving the text file, go back to the "GFS Meteogram for EHGG" site and click *Another Product*, just above the top graph. This takes you to the "Ready products for location: Groningen/Eelde –NL"
- The GFS models for 0-84hr are already selected, click *Go* in the "WINDGRAM" row.
- You are now taken to the "GFS Windgram" site. Leave everything as is, enter the given "access code" and click *Get Windgram*.
- This takes you to the site wit the "GFS Windgram for EHGG", showing wind barbs form 20 tot 1000 milibar pressure levels (1000mb equals ground level, the 850mb pressure level usually can be found at around 1500m altitude), four days in advance.
- Click with the *Text Results* at the bottom of the page with your right mouse, select "Save target as" and save the text file. Use the format YYYYMMDD_WNDGRAM.TXT to determine the filename.

- Copy both text files to the directory where you run the MATLAB scripts for BAM_migr_prediction

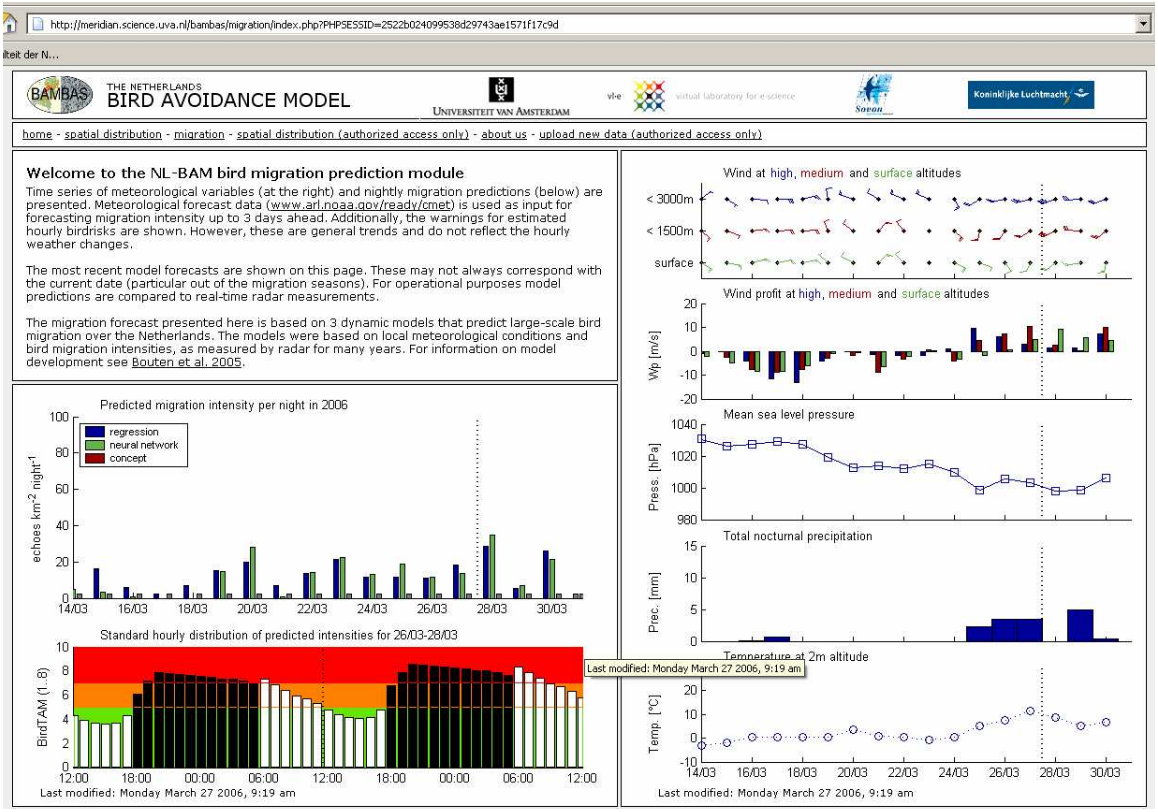
5.3 Running the MATLAB scripts

- Use the *Start* menu to start MATLAB (MATLAB will not open properly when clicking on any MATLAB file in the windows explorer!!)
- Select the location of the BAM_migr_prediction scripts as the "Current directory" (at the top of the MATLAB window.
- Type <BAM_migr_prediction>, <ENTER> in the "Command Window".
- Now the script is running: the meteorological data are extracted and saved to the MATLAB archive file "MainArchive.mat", nocturnal forecasts are calculated and added to the "MainArchive.mat" and hourly nocturnal and diurnal transformations are carried out.
- The resulting forecasts are shown as MATLAB graphs and automatically saved as -.png files in the directory of the BAM_migr_prediction scripts. "figure1.png" contains the bird migration intensity forecasts and "figure2.png" contains the meteorological forecasts The original meteorological text files are moved to the "..\backup\" directory.

5.4 Uploading the graphs

- Copy the automatically saved figures "figure1.png" en "figure2.png" to a computer with access to the internet.
- Open an internet browser and go the site of the migration module of the NL-BAM: http://ecogrid.sara.nl/bambas/migration/index.php
- Click *upload new data (authorized access only)*. Depending on the settings of your computer and on whether you have accessed a restricted BAMBAS site earlier, a login screen may pop up. If so, enter the access name and password that Floris Sluiter has provided you with.
- The upload screen allows you to upload the figures one at a time:
- Click *Browse* or *Bladeren* (depending on your browser's language), find and select the migration intensity forecast figure "figure1.png" and click *Open* or *Openen* to confirm your selection. Proceed in the upload screen:, select "figure1 (left side of the screen)" for "Select which image this is" and click *upload*, at the bottom of the page, to upload..
- Repeat the procedure for the meteorological forecast, "figure2.png", but select "figure2 (right side of the screen)" below "Select which image this is"!!

- After uploading both figures, click *migration*, at the top of the page, to check whether the migration and meteorological forecasts have been uploaded properly.



Screen shot of the NL-BAM migration module (http://ecogrid.sara.nl/bambas/migration/index.php)

5.5 Uploading the data

---Migration forecast data are not being saved on a central location yet---

The Spatial Distribution Module

1. Introduction

The spatial distribution module includes spatial density maps of the 62 bird species selected as most relevant for flight safety in the Netherlands in bi-weekly intervals, 4 time periods per day and at five altitude layers. This model is based on historic field observations and represents the density distribution expected in average circumstances. For information on the development of the spatial models see Appendix B4 (Shamoun-Baranes *et al.* 2005).

The key species were selected following several discussions based on criteria such as total number of birdstrikes, number of damaging birdstrikes, availability of data, mass, behaviour of birds, expert knowledge on species and conservation importance. The bird mass of each species was obtained from Dunning (1993). The spatial distribution of each species was modelled in relation to environmental conditions. This modelling procedure is described below. Furthermore, the altitude distribution of several species of birds was modelled in relation to meteorological conditions (see Appendix B5, Shamoun-Baranes *et al.* 2006).

2. Bird data

Numerous surveys monitor almost all the bird species that occur in the Netherlands at various periods in the year. Data are collected on sample sites with natural boundaries or on sample points. Monitoring of Dutch bird populations is in majority part of a governmental monitoring scheme which includes other organisms as well. These projects aim to detect changes in the natural environment, both in terrestrial and aquatic habitats. Coordination of fieldwork and data processing is mainly carried out by non-governmental organisations like SOVON Dutch Centre for Field Ornithology, in collaboration with Statistics Netherlands. Fieldwork for bird monitoring schemes is carried out by about 3000 volunteers and a small group of professional ornithologists.

For the production of the NL-BAM density maps, bird data from five different sources ('projects') were used (Table 2):

- PTT: Point-counts of non-breeding birds
- WAV: Water bird counts
- BSP: Casual observations of scarce species
- BMP: Counts of breeding birds in sample plots

- LSB: Colony breeding birds and rare breeding birds

Table 2. SOVON bird data sources used to develop the NL-BAM.

Non-breeding bird data				
Count description	*Abbreviation*	*Months/years*	*Numbers*	*Comments*
Winter bird counts	PTT	February: 1993-1997 August: 1988-1992 November: 1992-1996 December: 2000-2004	Observed individuals	
Water bird counts	WAV	Monthly: 1999-2004	Observed individuals	
Casual observations	BSP	Monthly: 2000-2005	Observed individuals	White stork and crane only
Breeding bird data				
Count description	*Abbreviation*	*Months/years*	*Numbers*	*Comments*
Breeding bird counts	BMP	2000-2004	pairs	only plots >= 10 ha
Colony Breeders	LSB	2000-2004	pairs	
Rare breeding birds	LSB	2000-2004	pairs	Hen Harrier

2.1 PTT: Point Transect Counts (Christmas Bird Count)

Since 1980, monitoring of mainly terrestrial wintering birds has been carried out annually along about 400 transects with 20 observation points each. A total of over 1000 transects have been monitored since the start of the project (figure 2a). In 2000-2004 more than 400 transects were monitored (figure 2b). Observers are requested to count all species at each point during exactly 5 minutes (Sierdsema *et al*., 1995). Initially, counts were made in November, December, February and August, but after an evaluation of the results in 1997, it was chosen to continue only the count in the 2nd half of December. Since 1978 more than 20000 points have been counted. From over 16000 points the exact location is known and digitised. For the year 2000 over 8000 data points were available.

In the counts no distinction is made between sedentary and flying birds. There is also no limit set to the distance within which birds may be counted or counts of birds in distance-bands. This is a minor problem in the establishment of trends, but a major difficulty in the establishment of densities. Therefore in 2001 part of the observers was asked to count bird numbers within and over a 200 meter band and to distinguish between sedentary birds and birds flying over. This made it possible to estimate the percentage of birds within 200 meters (56%) and birds flying over (2%). We assumed that this number is reliable estimate of the absolute number of birds.

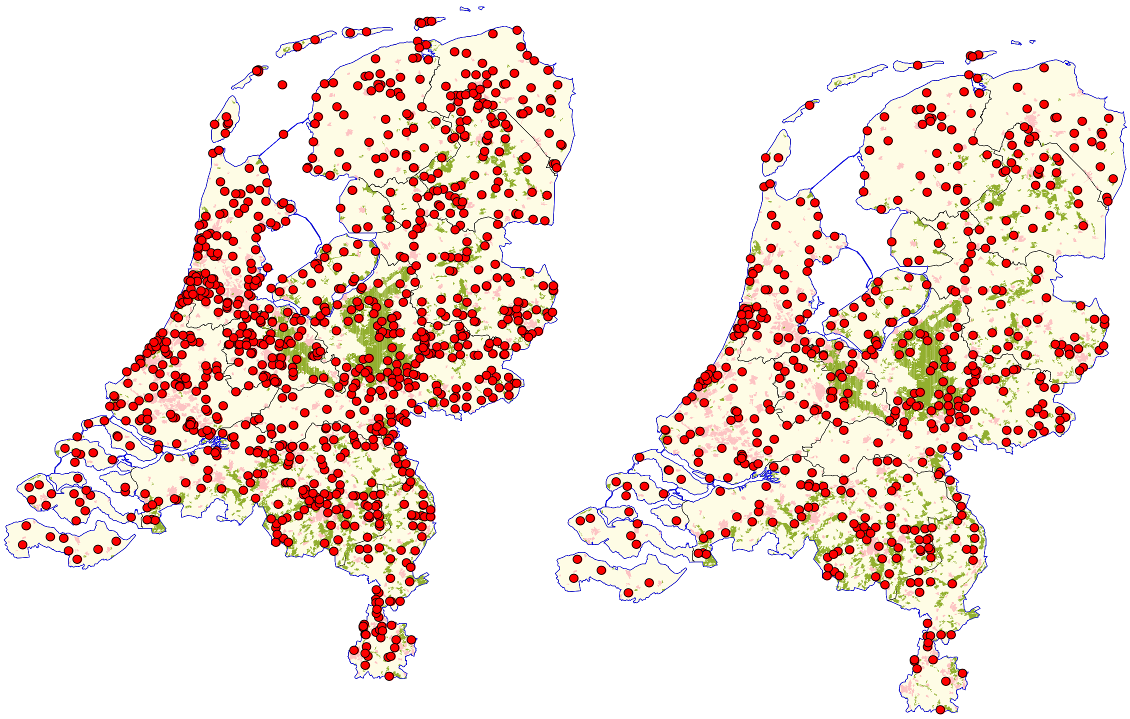


Figure 2. Location of all PTT-transects surveyed in 1978-2004 (2a, left) and in the period 2000-2004 (2b, right). Every point represents 20 census points.

2.2 WAV: Water bird Monitoring

Water bird counts are amongst the oldest biodiversity censuses in the Netherlands. As part of the International Water bird Census from Wetlands International, counts have already been conducted in the 1960s; for some goose species even data from the 1950s are available. Data collected in the framework of the water bird counts also played a major role in the new designation of Special Protection Areas in the Netherlands in 2000. The water bird monitoring programme currently includes monthly censuses in all important wetlands from September to April and monthly counts (including age-assessments) of geese and swans in agricultural areas between September and May. These counts are made possible through contributions of about 1100 volunteers and many regional governmental agencies. The counts in the Wadden Sea have been incorporated in a trilateral monitoring and assessment programme (TMAP), a collaboration between Denmark, Germany and the Netherlands. Data from some goose counts and the international midwinter count in January are transferred to Wetlands International and used to determine international trends and population estimates. Together with the British Isles, the Netherlands host the biggest concentrations of water birds in NW-Europe. For species like Greylag Goose, Barnacle Goose, White-fronted Goose and Bewick's Swan, even 75% or more of the NW-European population uses the Netherlands as a staging area during migration or winter.

2.3 BSP: Scarce migratory and wintering birds

Casual observations of scarce non-breeding bird species are separately collected. This project refers to species which are not considered by the rarities committee but are too scarce to be covered by e.g. the water bird monitoring programme or the point transect counts. Overall, more than 80 species are covered, including species like Red-breasted Goose, Red Kite, Merlin, Temminck's Stint, Waxwing and Great Grey Shrike. Analysis of these data has enabled detailed seasonal and geographical distribution patterns in the recently published Avifauna van Nederland 2 (Bijlsma *et al.* 2001).

2.4 BMP: Common Breeding Bird Census

The Dutch Common Bird Census (Broedvogel Monitoring Project; BMP), running from 1984 onwards, currently consists of five sub-projects, all using the combined mapping method for breeding birds in sample plots as a basis. The highly standardised censuses (van Dijk 2004) may concern all breeding bird species (with less intensive counts in urban areas) or only a fixed selection of rarer species, meadow birds or diurnal raptors. Approximately 1000-1500 census plots are investigated annually. A total of over 3400 plots have been surveyed since the start of the project (figure 3a). In 2000-2004 2166 plots have been surveyed (figure 3b). Most plots area located in woodland, farmland (although intensively managed farmland is under-represented) and natural habitat (coastal dunes, heath land, peat moors). Northern Lapwing, Willow Warbler, Eurasian Oystercatcher, Mallard and Winter Wren are the most numerous species within the sample. Trends are calculated according to habitat types (e.g. woodland, farmland, natural habitat) using standardised TRIM-software developed by Statistics Netherlands. The results are published in annual reports, and breeding indices of about 100 species are given on the homepage of SOVON as well (www.sovon.nl).

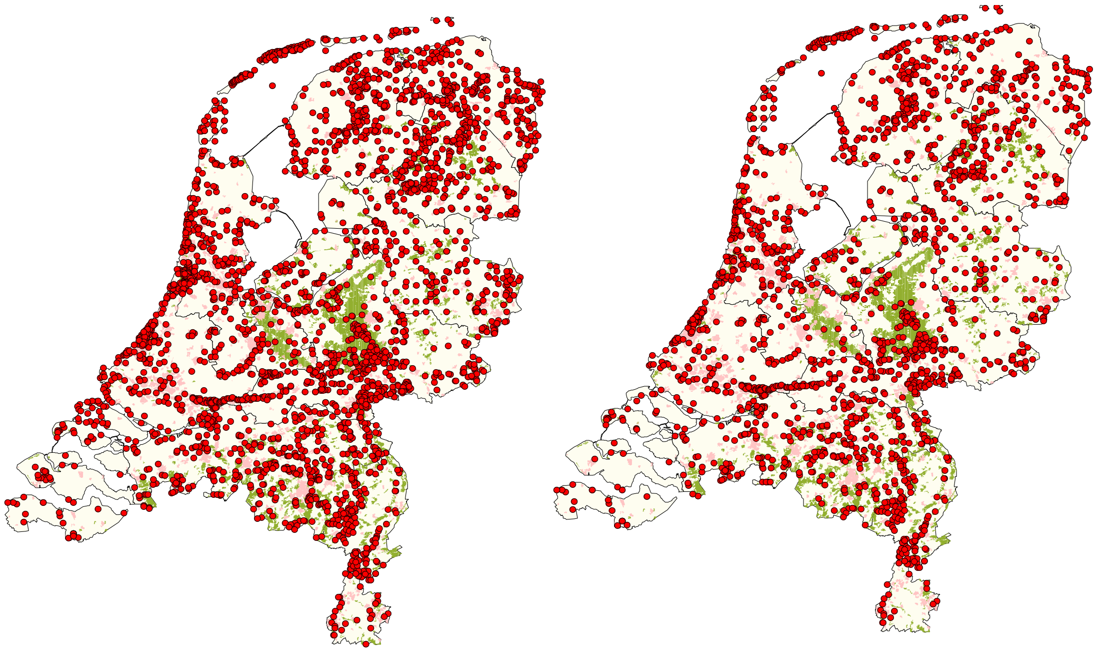


Figure 3. Location of all BMP-plots surveyed in 1984-2004 (3a, left) and in the period 2000-2004 (3b, right). For the latter period only plots >= 10 ha are shown.

2.5 LSB: Colonial and rare breeding birds

From 1985 onwards, a national breeding bird register for colonial and rare breeding species has been set up (van Dijk *et al.* 2004). This scheme included most species listed in the national Red List of threatened birds. For colonial birds and some scarce species (Hen Harrier, Black Grouse, Kentish Plover, Short-eared Owl), nearly the entire Dutch breeding population is covered annually. For other species, census efforts are primarily directed towards core areas (Great Bittern, Little Ringed Plover, Common Kingfisher), while in others all casual breeding records are collected (Crested Lark, Fieldfare). The census has enabled detailed knowledge on breeding numbers and distribution in 17 colonial species and some tens of other breeding species (van Dijk *et al.* 2003).

2.6 Avian data-processing

For each species, at least one data source was used in the modelling procedure. The data sources for each species included in the following analysis are summarized in Table 3; for a complete list of available data sources per species see Appendix A1. From these data-sources, all observations from last five years of available observation data (Table 2) were used to model the spatial distribution of each species.

Bird numbers in breeding bird data, such as BMP and LSB, refer to territories or "pairs". The actual number of individuals is not known, but approximated in most cases by two times the number of pairs (this factor is included in the risk_surface database, table "bam-species-selection" field "BreedingFACT").

First for each sample site, point or plot the average number of birds per species was calculated for the last 5 years of data described in Table 2. This average includes zero-counts. For PTT and WAV counts, data were averaged per month.

Only for colony breeders, rare breeding birds (Hen Harrier) and year-round distribution of Crane and White Stork no spatial interpolation or regression models of the count data were necessary to create national distribution maps. In all other cases spatial models were used to interpolate the data to get full spatial and/or temporal coverage.

Table 3. List of the primary and secondary key species, their mass and the data sources used to develop a spatial model for each species. species were removed from final NL-BAM.*

Scientific Name	*English Name*	*Primary species*	*Second. species*	*Mass*	*PTT*	*WAV*	*BSP*	*BMP*	*LSB*
Phalacrocorax carbo	Great Cormorant	Y		2.109		X			X
Ardea cinerea	Grey Heron	Y		1.443	X	X			X
Ciconia ciconia	White Stork		Y	3.473			X		X
Platalea leucorodia	Eurasian Spoonbill		Y	1.892		X			X
Cygnus olor	Mute Swan	Y		10.735		X			
Cygnus bewickii	Bewick's Swan		Y	6.05		X			
Cygnus cygnus	Whooper Swan		Y	9.35		X			
Anser serrirostris	Tundra Bean Goose	Y		2.521		X			
Anser brachyrhynchus	Pink-footed Goose	Y		2.645		X			
Anser albifrons	Greater White-fronted Goose	Y		2.58		X			
Anser anser	Greylag Goose	Y		3.309		X			
Branta canadensis ssp	Canada goose		Y	3.564		X			
Branta leucopsis	Barnacle Goose	Y		1.687		X			
Branta bernicla ssp	Brent goose		Y	1.3		X			
Alopochen aegyptiacus	Egyptian goose		*	1.875		X			
Tadorna tadorna	Common Shelduck		Y	1.152		X			
Mareca penelope	Eurasian Wigeon	Y		0.772		X			
Anas crecca	Common Teal		Y	0.341		X			
Anas platyrhynchos	Mallard	Y		1.082	X	X		X	
Anas acuta	Northern Pintail		Y	1.011		X			
Anas clypeata	Northern Shoveler		Y	0.638		X		X	
Aythya ferina	Common Pochard		Y	0.823		X		X	
Aythya fuligula	Tufted Duck		Y	0.694		X		X	

Scientific Name	***English Name***	***Primary species***	***Second. species***	***Mass***	***PTT***	***WAV***	***BSP***	***BMP***	***LSB***
Circus cyaneus	Hen Harrier		Y	0.436	X	X			X
Accipiter gentilis	Northern Goshawk	Y		1.025	X			X	
Accipiter nisus	Eurasian Sparrowhawk		Y	0.238	X			X	
Buteo buteo	Common Buzzard	Y		0.875	X			X	
Falco tinnunculus	Common Kestrel	Y		0.202	X			X	
Falco subbuteo	Eurasian Hobby		Y	0.24	X			X	
Perdix perdix	Grey Partridge		Y	0.39	X			X	
Grus grus	Common Crane	Y		5.5			X		
Haematopus ostralegus	Eurasian Oystercatcher	Y		0.526	X	X		X	
Pluvialis apricaria	European Golden Plover	Y		0.214	X	X			
Vanellus vanellus	Northern Lapwing	Y		0.219	X	X		X	
Calidris canutus	Red Knot		Y	0.137		X			
Calidris alpina	Dunlin	Y		0.047		X			
Gallinago gallinago	Common Snipe	Y		0.122	X	X		X	
Scolopax rusticola	Eurasian Woodcock		Y	0.31				X	
Limosa limosa	Black-tailed Godwit	Y		0.291	X	X		X	
Limosa lapponica	Bar-tailed Godwit	Y		0.343		X			
Numenius arquata	Eurasian Curlew	Y		0.806	X	X		X	
Tringa totanus	Common Redshank		Y	0.129	X	X		X	
Larus ridibundus	Black-headed Gull	Y		0.284	X	X			X
Larus canus	Mew Gull	Y		0.404	X	X			X
Larus graellsii	Lesser Black-backed Gull	Y		0.818		X			X
Larus argentatus	European Herring Gull	Y		1.135		X			X
Larus marinus	Great Black-backed Gull		Y	1.659		X			X
Sterna hirundo	Common tern		*	0.12		X			X
Columba oenas	Stock Dove	Y		0.291	X			X	
Columba palumbus	Common Wood Pigeon	Y		0.49	X			X	
Columba domestica	Feral Pigeon		*	0.354	X			X	
Apus apus	Common Swift	Y		0.038	X			X	
Alauda arvensis	Eurasian Skylark		Y	0.04	X			X	
Hirundo rustica	Barn Swallow	Y		0.016	X			X	
Delichon urbica	Common House Martin	Y		0.015	X			X	X
Anthus pratensis	Meadow Pipit		Y	0.018	X			X	
Motacilla alba	White Wagtail		Y	0.021	X			X	
Turdus pilaris	Fieldfare	Y		0.011	X				
Turdus philomelos	Song Thrush	Y		0.068	X			X	

Scientific Name	English Name	Primary species	Second. species	Mass	PTT	WAV	BSP	BMP	LSB
Turdus iliacus	Redwing	Y		0.061	X				
Corvus monedula	Western Jackdaw	Y		0.246	X			X	
Corvus frugilegus	Rook		Y	0.488	X				X
Corvus corone	Carrion Crow		Y	0.57	X			X	
Sturnus vulgaris	Common Starling	Y		0.082	X			X	
Fringilla coelebs	Common Chaffinch	Y		0.021	X			X	

3. Land use data sources and processing

A number of datasets were used to create the predictive variables for the regression models. These are:

- Physical Geographical Regions
- National Land use map 2004
- Ground water tables
- Openness of the landscape
- Distribution of grasslands managed as nature reserve

Following is a brief description of the data sets. More information, in Dutch, can be found on http://geodesk.girs.wau.nl/geokey4 .

3.1 Physical Geographical Regions

Within the Dutch nature policy a division of the Netherlands in physical geographical regions is used. This is a large-scale division, based on the major soil type of the region (figure 4a). From this map the individual subregions were used as descriptive variables. For example, instead of the region 'Laagveen' ('LV') the subregions 'Laagveen-noord' ('LVN') and 'Laagveen-Holland' ('LVH') were used. The division into subregions accounts for soil type, general land use and broad spatial trends in densities. Some subregions, likes ‘DYKES’ or ‘ North Sea’ with very few observations were regionally joined or split-up (figure 4b). Each census plot or kilometre square was assigned to the region with the largest area.

3.2 National Land use map 2004

The National Land Use Map 2004 has been composed based on data from the TOP10-vector land use map, satellite information from the LGN-map and some other sources (Pouwels *et al.* 2005). This is a grid-map with pixels of 25 meter. The map has 36 legend items with varying types of forest, marshland, urban and agricultural land use (figure 5).

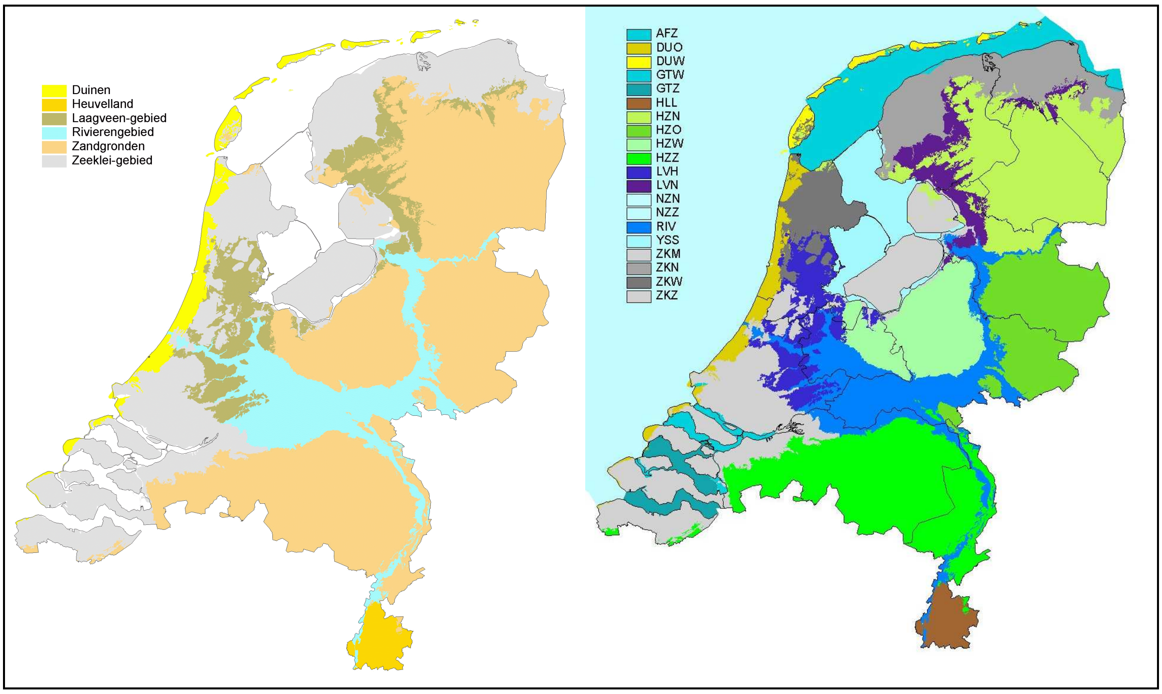
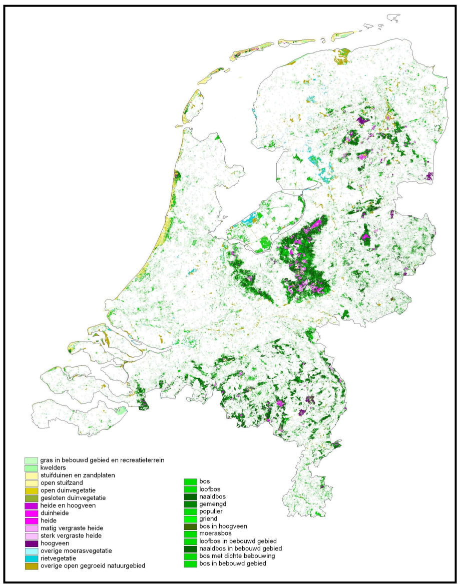


Figure 4. a) Major physical geographical regions (left) b) Physical geographical sub-regions (right)

Legend items in the National Land Use Map 2004 were combined to higher and lower order ecotopes. Higher order ecotopes, like forest or marsh, were called 'hoofdecotopen'. Lower order ecotopes, like deciduous and coniferous forest, were called 'subecotopen'. All items were also classified as agriculture, nature or urban. For all plots and kilometre squares the percentage per land use at different levels was calculated.



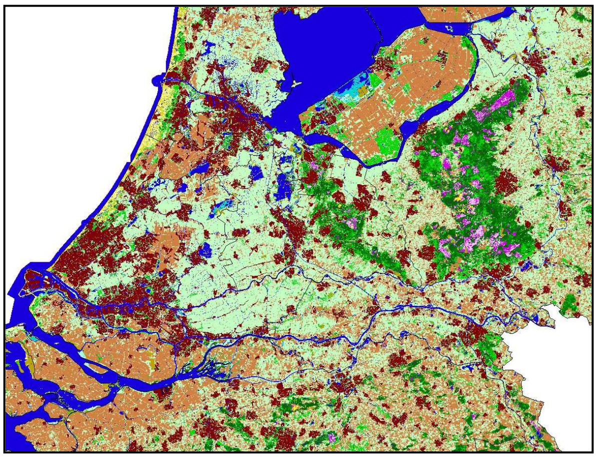


Figure 5. National Land use Map 2004 (Ecotopenkaart) (left) and detailed map (right). Not all units are depicted.

3.3 Ground water tables

Information about the average of the highest and lowest ground water levels (figure 6a) is stored within the national map of soil types (Steur & Heijink 1991). By the ground water tables information is given on. The 63 legend items in the groundwater map were combined in 6 classes from very wet to very dry. Classes 1 and 2 were also combined in the variable 'nat' ('wet'). For all plots and kilometre squares the percentage ground water class was calculated.

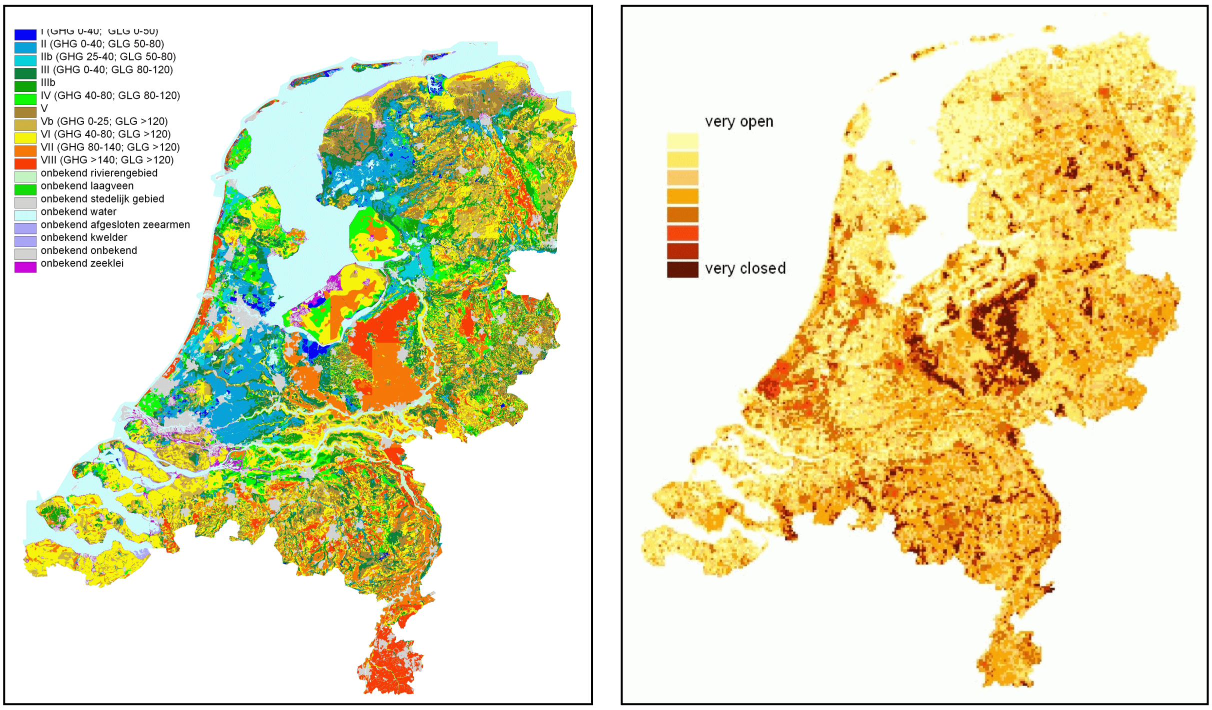


Figure 6. a) Ground water tables (left); b) openness of the landscape(right).

3.4 Openness of the landscape

Based on the TOP10-vector several maps describing the scale characteristics of the Dutch landscape have been made (Dijkstra & Kranendonk 2000). One of these maps describes the openness of the landscape on the scale of square kilometres. The 1 km-grid, however, is not very suitable to describe the openness of the landscape in plots with natural boundaries. Therefore the km-grid has been interpolated with kriging to a 25 meter-grid version (figure 6b). This map has a continuous scale of 0-100. The average of the openness per plot or kilometre square was used as predictive variable.

3.5 Distribution of grasslands managed as nature reserve

Grasslands managed as nature reserve are known to hold different bird composition as compared to ordinary, intensively used, grasslands. For nature policy purposes a vector-map has been made with all the grasslands that are managed as nature reserve. As a descriptive variable the percentage of nature grasslands per plot and km-square was calculated.

4. Spatial models

4.1 Regression kriging overview

Regression kriging was carried out in two steps. First a general additive model (GAM) was fit and predictions for all data-points were calculated. Then the difference between the counts and the predictions ('simple' or 'response' residuals) was calculated by subtracting the fitted values from the data. These residuals were spatially interpolated with ordinary kriging, resulting in a 1 km^2 map with complete coverage for the Netherlands of the residuals. This method differs from the general method as described in Appendix B6 (Sierdsema and van Loon, *submitted*). Instead of solving one equation the process has been split in two separate steps. We have chosen this method because the combination of GAMs and kriging is not possible yet in the available software (GSTAT) and very computational intensive with other software.

Final maps were obtained by adding the estimated number of birds from the GAM to the predicted value of the residual.

The average bird number or pairs per plot, depending on the count technique, were used as the dependent variable in the regression models. Table 4 lists the various independent variables and their source as well as the bird data sources for which they were used. In data sources with more than one count per year (WAV, PTT) all variables were modelled as an interaction with month, accounting for changes in relationships during the year.

4.2 Count specific information

The description of all individual models, including the variables and parameters per model are available on CDROM.

Table 4. Environmental predictive variables and their sources used in various regression models

Variable	*Source*	*Model*	*Remark*
Fysical Geographical sub region	Fysical Geographical sub regions	all	
X- and Y-coordinate		PTT, BMP	Accounting for large scale spatial trends
Landuse: top-classification (nature, agriculture, urban)	Ecotopenkaart	PTT, WAV, BMP	
Landuse: higher order (11 variables)	Ecotopenkaart	PTT, WAV, BMP	
Landuse: lower order (19 variables)	Ecotopenkaart	BMP	
Ground water table (6 classes)	Ground water map	PTT, WAV, BMP	in particular %wet
Openness landscape	Top10 vector / Openness landscape	PTT, WAV, BMP	as 3rd degree spline
Nature grassland (%)	Grasslands managed as nature reserve	PTT, BMP	

4.2.1 BMP: Breeding birds

The variables used for individual species depended on their major land use, like forest of farmland birds, and abundance. In general, the number of variables in the model decreased with the number of positive observations. Interactions between the predictors were tested, but resulted in most cases in extreme predictions in strata with no of very few observations. A histogram of the actual densities in the plots and the predictions was created to compare the distributions and to look for extreme predictions.

4.2.2 PTT: Winter birds

In almost all species the same regression model was used. This included:

- Area in hectares as offset-variable
- Month
- The descriptive variables described in table 4.
- The interaction between month and a series of descriptive variables. The interaction was used to account for differences in the relation between bird numbers and descriptors in different months.

4.2.3 WAV: Water birds

In almost all species the same regression model was used. This model included:

- Month
- The descriptive variables described in table 4.
- The interaction between Month and a series of descriptive variables. The interaction was used to account for differences in the relation between bird numbers and descriptors in different months.

5. Model validation and final processing

The results of the automatic mapping process were validated based on expert opinion. Validation was mainly based on the following presumptions:

1. There should be no abrupt changes in numbers from one period to the other
2. Distributions should be similar to distribution maps in SOVON-reports and bird atlases:
   (1) Breeding atlas 1998-2000 (SOVON Vogelonderzoek Nederland 2002)
   (2) Water bird report with distribution and numbers in 2002/3 and a summary of 1997-2001 (van Roomen *et al.* 2004)
   (3) Atlas of geese and swans in The Netherlands (Voslamber *et al.* 2004)
   (4) Year-round atlas of the birds in The Netherlands (period 1978-83) (SOVON 1987)
   (5) PTT monitoring project report, 1980-2004 (Boele *et al.* 2005)

If the automatic process resulted in aberrant distribution patterns, the source of this aberration was located. In many cases this was the interpolated map of the residuals. Abrupt changes in numbers were levelled off in most cases by setting a different multiplication factor for the breeding bird data. This factor was standard 2 and does therefore not take into account the non-breeding part of the population (risksurface database, table “bam-species-selection”, field “BreedingFACT”).

Three species, Egyptian goose, common tern and feral pigeon were omitted because no reliable abundance maps could be produced with the current mapping procedure.

For all the maps created from the Waterbird counts (WAV counts) the kriging maps of the residuals very often produced aberrant maps. This is due to the fact that the SOVON database mainly contains counts of sites with many water birds. Although non-counted sites are likely to hold no or a few birds, they are treated as missing data in the database. Kriging of the residuals therefore tends to overestimate the numbers in the non-counted areas resulting in poor quality abundance maps. It was finally decided not to use the kriging maps of the residuals for this dataset. The biased dataset also resulted in predictions of birds where they are less likely to occur. Therefore a mask for different groups of waterbirds, like coastal birds and gulls, was created to delete these unlikely predictions from the maps.

See Appendix A2 for a descriptive species specific summary of the model validation phase for the spatial distributions. Total numbers for each seasonal period (24 periods) per species, following time of year adjustments (see following section) was also validated using the same data sources and expert knowledge as mentioned above. For several species, total numbers appear to be quite inaccurate and are documented in Appendix A3. However, models have not been altered following this review phase and remain a task for future improvements of the spatial module of the NL-BAM.

6. Model integration with BAMBOX 3.1

Unless otherwise noted all lists mentioned below are included in the '**risksurface.mdb**' database supplied on CD-ROM with this report. In the following text, database files will appear in bold and matlab files will appear in bold italics.

6.1 The content of the "risksurface" database

This is a database containing all pertinent information needed for the modelling procedures for NL-BAM 1.0 that are not included in other data sources (such as bird observations or land use data sources).

Basic information on all species considered for the BAM is included in the table **BAM-species-selection**. A species list of 65 primary and secondary species was selected for modelling for discussions of the entire BAMBAS team and a final decision reached by Arie Dekker, Hans van Gasteren and Henk Sierdsema. (query: **species_list**). The taiga bean goose (Euring 1571) was eliminated from original list due to its rarity and the lack of modelled maps, the Egyptian goose, common tern and feral pigeon were also eliminated due to modelling problems.

The mass of each species in the database was compiled from Dunning 1993. When mass was available for both male and female specimens a mean was calculated and included in the database. The mass is included in the **BAM-species-selection** table and the **species_list** query.

The expert interview form (see Appendix A4 for blank form, CD-ROM for completed forms) was used to complete information on the altitude distribution, time of day, time of year (annual abundance) and activity factor (the maximum proportion of birds in the air table:

factor). These data were compiled by Arie Dekker, Hans van Gasteren, Judy Shamoun-Baranes and Henk Sierdsema. Generally factors that have not been compiled during the expert interviews were compiled by Henk Siersema.

TimeOfYear table: values of 0-1 for two-week periods per species, proportion of population in the Netherlands at each time frame. This is based on GORS data (RNLAF airfield observation database), LWTV visual observation migration data (LWVT/SOVON, 2002), SOVON waterbird counts (van Roomen et al. 2004), expert knowledge or a combination of the different sources. When only the waterbird count is used, indexes (scaled to 1) are available for the 15th of each month and were provided by Henk Sierdsema (table: **waterbirdindex**). An interpolation method was written in matlab in order to calculate biweekly indexes (***runningmean.m***). This method also results in similar bi-weekly indices as with using the Matlab command ***interp1***. The resulting file **WB_24_index** is then imported into the database and merged in access with the **TimeOfYear** table.

TimeOfDay table: values of 0-1 for the proportion of birds that are active each period per species.

Times of day are defined as follows:
sunrise - 1hr > DAWN < sunrise + 1 hr
sunset - 2 hr > DUSK < sunset + 1 hr
Day and night is everything in between

Altitude table: values of 0-1 for each altitude band per species. For a few species there are different altitude distributions for different times of day. Altitude distribution was established based on expert opinion, Eurbase birdstrike data and flycatcher measurements conducted by the RNLAF.

6.2 The BAMBOX TOOLBOX

The matlab ***BAMBOX 3.1 toolbox*** has been written and used to read pre-processed environmental and count data and then create distribution maps based on the selected modelling techniques per species/ time of year/ time of day and altitude layer as well as combined maps for number birds and mass. Several plotting functions are also included to allow for visual comparison of maps, calculation of total numbers per map and identification of errors.

Based on various sources of SOVON count data, regression models of the spatial distribution of each species in the units of birds/km^2 were created as described previously. For the breeding bird maps (BMP) and the colonial birds maps (LSB) the unit modelled is pairs/km^2. Following regression kriging, pairs must be multiplied by a breeding bird factor (2 by default) to convert to birds/km^2 – this value has been added as an extra field "breedingFACT" in the table **BAM-species-selection**. These values can therefore be altered if needed.

Following is a description how the toolbox works and the order with which different commands should be used (figure 7). First a direction BAMBOX 3.1 should be created. The toolbox should be extracted maintaining folder structure. Several new folders will be created and the raw regression data included. The program ***mk_all***, would run all procedures from start to finish finally creating all files necessary, in their appropriate file structure, for the spatial distribution website. Additional plotting can be done for visualization and review of most of the mapping procedures. Almost each function described below has a complementary plotting function which starts with the prefix ***plt_*** rather than ***mk_***. The m-file ***mk_all_plt_all*** would do the same as above, including also all relevant plotting commands.

6.2.1 Mapping procedures and relevant scripts

1. ***mk_regression_maps***, structures the regression output for use in Matlab. Maps are created in the subdirectory 'B_regression_maps'.

   The function reads the source data for one survey (e.g. BMP_pred.txt) from the sub-directory 'A_source_data', reformats each of the columns with bird counts into a 325 by 280 array, saves each of the arrays in a separate mat-file. When printing the map, a color scale is defined from 0 to the 95 percentile of the data range (excluding the zeros when calculating the 95 percentile).

2. ***mk_kriging_maps***, performs kriging per dataset according to the variogram and masking specifications provided in the **kriging** table. If kriging is omitted from the modelling process, it is indicated in this table. Maps are created in the subdirectory 'B_kriging_maps'.

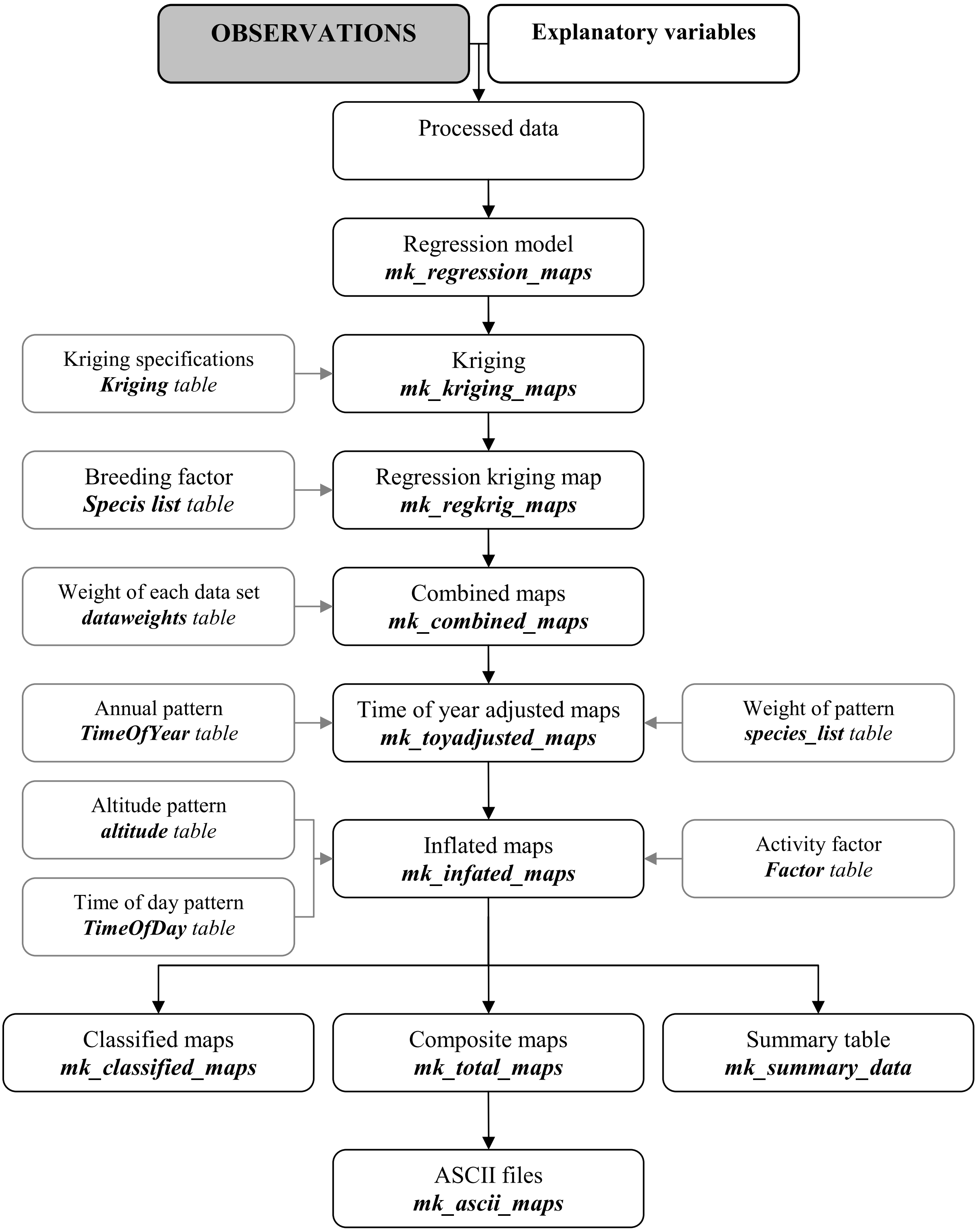


Figure 7. Flow chart describing the modelling and processing procedures used to produce the NL-BAM maps. Boxes outlined in grey represent supporting information needed to perform specific tasks (central boxes).

3. ***mk_regkrig_maps***, combines kriging and regression results to create regression-kriging maps per species per dataset. Maps are created in the subdirectory 'C_regkrig_maps'.
   Breeding factor: The BMP and LSB maps per species are all multiplied by a breeding factor, which is correction factor to transform pairs of birds counted to numbers of birds counted. The default value is 2. (query: **species_list**, field: **breedingFACT**).

   The output from regression-kriging is stored in textfiles per bird survey-type. The structure of the text files with prediction data is as shown below.

```
"Plotnr";"Kmhok";"Opp";"X";"Y";"Maand";"DH_01520";"DH_01610";"DH_01860";'
;"014453";100.00;157500.00;605500.00;5.00;0.04;1.02;14.02;2.25;0.71;1.90;
;"014454";100.00;158500.00;605500.00;5.00;0.02;0.55;8.07;1.20;0.25;0.90;(
;"014455";100.00;159500.00;605500.00;5.00;.472191000000000E-2;0.28;4.46;(
;"014541";100.00;160500.00;606500.00;5.00;0.03;0.87;11.77;1.73;0.55;1.68;
;"014542";100.00;161500.00;606500.00;5.00;0.01;0.48;6.55;0.74;0.20;0.76;(
;"014543";100.00;162500.00;606500.00;5.00;0.01;0.29;5.07;0.63;0.09;0.39;(
;"014544";100.00;163500.00;606500.00;5.00;.364017000000000E-2;0.19;4.47;(
```

   Each row in the textfiles contains the information for one 'Kmhok'. The texfiles contain six general columns with the following contents:

   Plotnr: the code of the plot for which the data are applicable (in text files with observation data this column contains values, in the text files with prediction data it is empty)

   Kmhok: the code for the 'Kmhok'- a 1D coding of the Dutch coordinate system

   Opp: the surface of the plot or Kmhok in ha. (100 ha for a Kmhok)

   X: the x-coordinate of the Kmhok-center (Amersfoort coordinate system)

   Y: the y-coordinate of the Kmhok-center (Amersfoort coordinate system)

   Maand: the month for which the data is applicable (number from 0 to 12)

   The remaining columns (e.g. with header DH_1520, DH_1610 etc.), contain the number of birds (in the case of PTT, WAV and BSP data) or the number of breeding pairs (BMP and LSB) surveys.

4. ***mk_combined_maps***, this procedure combines the different data sources to model the spatial distribution of each species for 24 2-week periods. Separate maps are created in the subdirectory 'D_combined_maps'.

   For different groups of birds, different source data are available. For example for some species, only the breeding bird maps and the winter counts, for other species, monthly waterbird counts are available as well. For each species a weighting system has been established by Henk Sierdsema to determine the relative weight of each map needed for this modelling procedure (table: **dataweights**). The Matlab function uses a weighted combination of the separate maps according to the relative weights in table **dataweights**.

The weighting scheme works as follows. For a certain bird and BAM period, there may be a number of contributing maps. First, all contributing maps for which the weights are lower or equal to 1 are combined. The weights for these maps should sum to 1. Next, this average map is combined with the contributing maps for which the weight is 2, by superimposing the maps and taking the maximum of the two maps for each map-element. For each bird and BAM period there is at least one contributing map, there can be many contributing maps with weights smaller than one (however the sum of these weights should sum to 1), and many contributing maps with weights set to 2.

The function saves each set of 24 arrays per bird into a 325 x 280 x 24 array, and saves each of these in a separate mat-file. Each set of 24 maps can be printed to a png-file (***plt_combined_maps***). When printing the 24 maps, a color scale is defined from 0 to the 95-percentile of the data range over all 24 maps.

5. ***mk_toyadjusted_maps***, this procedure adjusts the combined maps with prior information about total yearly abundance patterns. Separate maps and images are created in the subdirectory 'E_toyadjusted_maps'.

   The Matlab function ***mk_toyadjusted_maps*** is used to combine prior information about seasonal pattern of annual bird abundance per species with the combined maps. The function reads data per bird species from the directory 'D_combined_maps'. In addition, the '**TimeOfYear**' pattern (TOYprior), as well as the weight that has to be given to this TOY pattern (**'wgtTOYValue'** in query **species_list**) are read from the database. The default weight is set to 0.5 but can be increased to any value up to 1 and has been adjusted per species.

   The pattern of total bird abundances for the Netherlands (over the 24 BAM periods) is calculated for the combined maps by simple summation over each of the 24 maps. Next, the pattern is normalized by dividing the 24 numbers by the maximum out of these. The combined maps are corrected by multiplying with a factor TOYposterior. This is calculated as follows:

   TOYposterior = TOY_regression + (TOYprior - TOYregression)*TOYwgt

Finally, the resulting set of combined maps, adjusted for time of year (so-called TOYadjusted maps), are written to the directory 'E_toyadjusted_maps'. Currently this is the mean of to TOYprior and the TOYregression.

6. ***mk_inflated_maps***, this procedure generates distribution maps per time of year, time of day and altitude layer and generates 480 maps per species from the 24 maps per species generated in step 5. Separate maps are created in the subdirectory 'F_inflated_maps'.
   Mass: In step 7 maps are generated for birds/km2 but also for mass. Therefore, each of the 24 maps generated in step 5 are multiplied by the bird mass (query: **species_list**, field '**mass'**).
   Activity: The 24 maps per species are all multiplied by an activity factor, which is an estimate of the maximum proportion of birds in the air at any one time. This factor ranges from 0.01 – 1. (table: **Factor**).
   Time of day: Maps are calculated for 4 times of day, (Dawn, Day, Dusk, Night) scaled from 0-1. (table: **TimeOfDay**).
   Altitude: Maps are calculated for the 5 altitude layers per time of day, time of year combination, the sum of the altitude distribution is 1. (table: **Altitude**).

7a. ***mk_classified_maps***, in this procedure maps are classified into 8 classes, creating a second set of 480 maps. The classes are designated as 8 equal interval classes by calculating the 95 percentile of all maps per species, and dividing this value by 8 to calculate the intervals. The resulting mat files begin with a 'c'. Species specific map legends are also created during this procedure. Separate maps are created in the subdirectory 'G_classified_maps'.

7b. ***mk_classified_maps_logscale***, in this procedure maps are classified into 8 classes, creating a third set of 480 maps. The classes are designated as 8 classes on a logarithmic scale from 0 to 32. In this way all species maps are on the same scale. The resulting mat files begin with a 'c'. Species specific map legends are also created during this procedure. Separate maps are created in the subdirectory 'G_classified_maps_logscale'.

8a. ***mk_total_maps***, in this procedure the maps of all species are combined to create 480 maps of total number of birds/km^2 and total mass/km^2. Separate maps are created in the subdirectory 'G_classified_maps'.

8b. ***mk_total_maps_logscale***, in this procedure the maps of all species are combined to create 480 maps of total number of birds/km^2 and total mass/km^2. These birds/km^2 are classified maps are on a logarithmic scale from 0 to 125 and the kg/km^2 from 0 to 125. Separate maps are created in the subdirectory 'G_classified_maps_logscale'.

9. ***mk_summary_data***. The summary table is created where the total number of birds is calculated per region (for 3 regions) per time of year, time of day and altitude layer, for the top 10 most abundant species. Regions are defined in the ASCII file: bamregkm.asc. A text file is written to the subdirectory: H_output_data.

   The summary table is created in the following form:

   toy int4 NOT NULL,
   tod int4 NOT NULL,
   alt int4 NOT NULL,
   reg int4 NOT NULL,
   euringcode int4 NOT NULL,
   ned_name text NOT NULL,
   eng_name text NOT NULL,
   wet_name text NOT NULL,
   total int4 NOT NULL

   for example: 1,1,1,1,9920,Boerenzwaluw,Barn Swallow,Hirundo rustica,16232

10a. ***mk_ascii_maps***. In this procedure all ascii maps and legends that are uploaded to mapserver are created with the appropriate file naming convection. The classified maps and the appropriate legends are stored together in species specific zip file: ceuring.zip and each file has a relative path ceuring\data\. Finally all files are zipped into cdata.zip with the appropriate folder structure.

   Naming conventions are as follows:

   beuring_TOY_TOD_ALT.asc (e.g. b1970_1_DAY_5.asc) numbers
   ceuring_TOY_TOD_ALT.asc (e.g. b1970_1_DAY_5.asc) classified map
   ceuring_TOY_TOD_ALT.leg (e.g. b1970_1_DAY_5.leg) legend

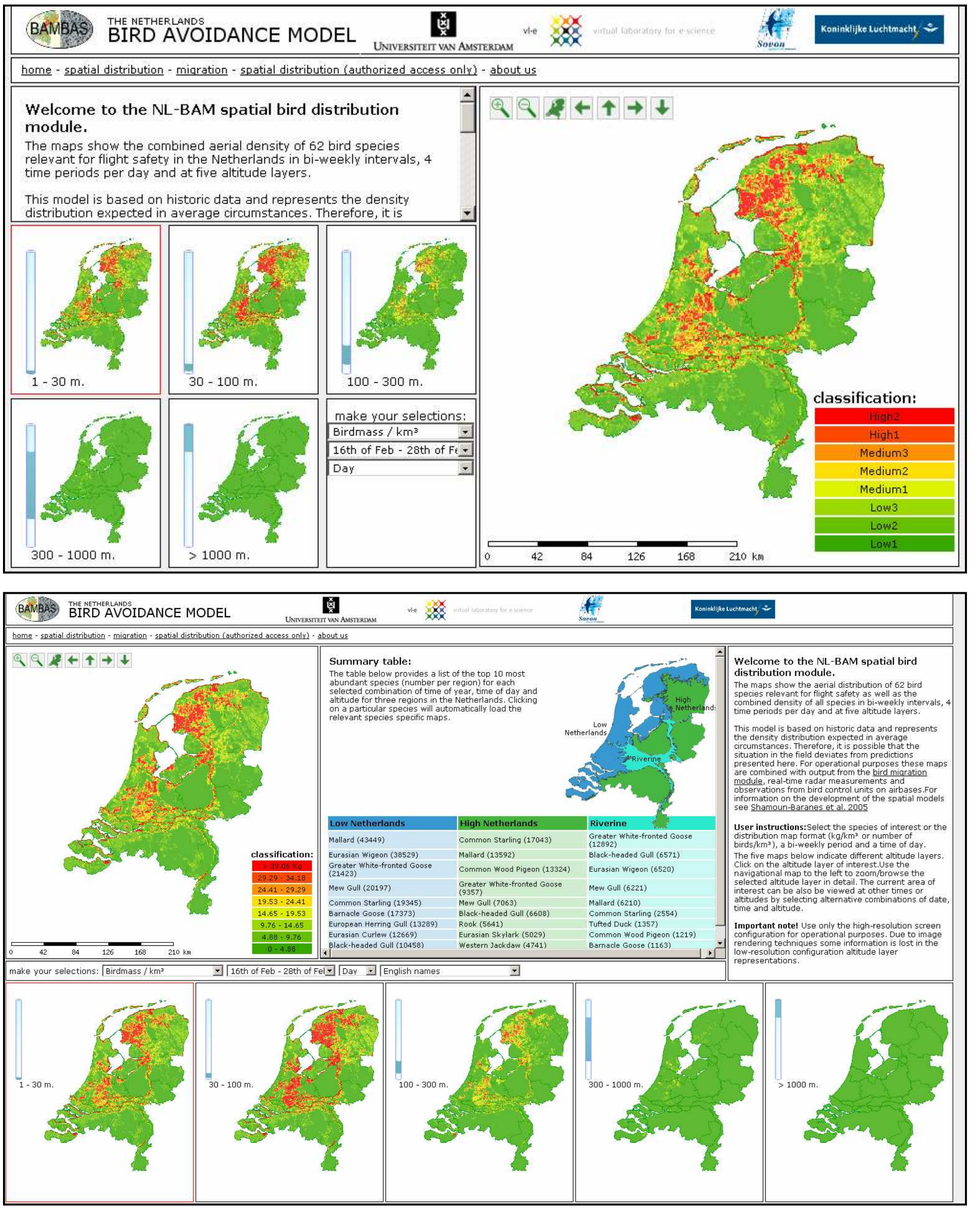
10b. ***mk_ascii_maps_logscale***. As in 10a all ascii maps and legends with a logarithmic scale are created and uploaded to mapserver. However, these files can only be viewed on a secondary internal NL-BAM site: http://ecogrid.sara.nl/bambas_logscale/

6.2.2 Reviewing process

Several review processes occur through visualization in Matlab in the BAMBOX 3.1 toolbox:

1. **First review** after production of raw regression maps developed per species per survey technique (***plt_regression_maps***)
2. **Second review** after production of regression kriging maps (***plt_regkrig_maps***)
3. **Third review** after production of 24 time of year adjusted maps per species (***plt_toyadjusted_maps***)

4. **Fourth review** after production of 480 maps/species of a small selection of birds. (***plt_inflated_maps***)



Screenshots of the NL-BAM spatial distribution module: public access (top, http://ecogrid.sara.nl/bambas/distribution/index.php) and authorized access page with summary table (below, https://ecogrid.sara.nl/bambas/distribution_authorized/index.php).

Conclusions

Within only three years the BAMBAS team has developed a comprehensive Bird Avoidance Model for the Netherlands which predicts the distribution and density of birds at different scales in space and time. The huge wealth of information made available from models and measurements is easily accessible through an user friendly web interface developed using predominately open source software. Each module has its own strengths and weakness and of course there is always room for improvement. Nevertheless we can be confident in our modelling techniques and our rigorous calibration and validation schemes. Furthermore, the publication of the models and results in scientific literature following peer review will set this project apart from others where scientific publications is not a requirement. This ensures that our work is scrutinized by the outside scientific community, giving further support to its scientific integrity.

Within the framework of the BAM project a EuroBAM network has been established, in cooperation with the Bird Avoidance Modelling IBSC working group. Two very successful meetings were held in the Netherlands and a third is planned for spring 2006 in Germany in Traben-Trarbeh. People from consulting agencies, air forces, universities and research centers from Belgium, Denmark, Germany, Norway, The Netherlands, Switzerland the UK and the US have participated. This type of expertise exchange and networking between different groups keeps all parties informed of progress in the fields related to bird avoidance modelling and measurement schemes and will hopefully help in the development of larger scale models, or integration of national models to increase spatial coverage in Europe and even beyond.

Finally, although much has been accomplished within the current project there is much more to be done. Ideas for future projects are numerous and range from technical in nature to a “wish list” of improvements stemming from the current BAM to more fundamental biological or behavioural questions, again all applicable to the science of bird hazard avoidance. Cleary the cooperation between academic institutes, conservation organizations and the air force can make advances in this field of science. Below is a short list of just some of the ideas that have been discussed and should not only remain in this report, but hopefully become active projects in the near future.

From a Bird Avoidance Model to a Bird Avoidance System

Following is a list of some potential projects for improving the BAM and developing a BAS.

1. The migration model.

1a. Recalibration of the migration models on the basis of ROBIN4 data and NOAA meteorological data.

1b. Test the usefulness of the Erni-model for prediction purposes: sensitivity analyses; include migration departures; reduce parameter ranges on the basis of radar measurements and inverse modelling; compare with other results of migration models

1c. Modelling flight altitude during migration in relation to weather and coupling this with the current migration intensity model.

1d. Analysing the differences of migration dynamics of the three radars

1e. Next step in setting up a weather radar network for bird migration studies

2. The spatial model

2a. Improvement of spatial models of the more difficult species by rigorously testing different modelling strategies, including bootstrap analysis, consideration of different explanatory variables, and tuning of various factors.

2b. Create a 1 to 8 scale for the spatial distribution module that is comparable to the scale used in the migration module and BirdTAMs. This would mean that a scale of 8 truly reflects an extremely hazardous situation.

2c. Model distribution on the ground in relation to ice or snow cover to improve spatial models for a number of key species (particularly geese) and include this dynamic component on the internet.

2d. Dynamic integration of the influence of weather on flight altitudes and include this dynamic component on the internet. This would require new research including additional field work to establish general patterns of flight routes, altitudes, and time budgets, especially on and around air fields.

2e. Develop spatial models at the air field scale. Link spatial distributions, as observed on air fields, with the SOVON maps. Analyse differences that may be caused by management.

3. EUROBAM

3a. Development or integration of models at a larger scale. For example, integrating migration models developed by different countries, integrating different resources or expanding spatial distributions using national data sources and currently developed methodology.

3b. Expanding the use of existing radar systems (e.g. C-Band radar) for real time bird migration warnings and/or large scale migration model development. (cf. 1e)

Acknowledgments

This project was funded by the Royal Netherlands Air Force, The University of Amsterdam and the Virtual Laboratory for e-Science project (www.vl-e.nl). We would like to thank participants of the EuroBAM network meetings for fruitful discussions as well as, Russel Defusco and Eugene LeBoeff for providing information and expertise about the US-BAM. Meteorological data was provided by KNMI, ECMWF and NOAA. Finally, to the many volunteers responsible for collecting field data and the students of CBPG that assisted in various BAM related tasks.

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List of Appendices A: Tables and forms

1. List of available data sources for the primary and secondary key species.
2. Descriptive species specific summary of accuracy of spatial distribution.
3. Descriptive species specific summary of accuracy of total numbers for spatial distribution models.
4. Expert interview form.

List of Appendices B: Reports and Publications (printed separately)

1. Bouten, W., van Belle, J. Vrugt, J. Shamoun-Baranes, J. and Buurma, L.. 2005. Predicting bird migration: data-driven versus concept – driven models. *Proceedings of the 27th International Bird Strike Committee Meeting*, Athens.
2. van Belle, J., Shamoun-Baranes, J. and Bouten, W. (*in prep)* Can weather-based regression models predict autumn bird migration intensity?
3. van Gasteren, H, 2005. Using parameter identification for optimising a conceptual bird migration model, internal report BAMBAS project.
4. Shamoun-Baranes, J., Sierdsema, H. van Loon, E. van Gasteren, H. Bouten, W. and Sluiter, F. 2005. Linking horizontal and vertical models to predict 3D + time distributions of bird densities. *Proceedings of the 27th International Bird Strike Committee Meeting*, Athens.
5. Shamoun-Baranes, J., van Gasteren, H., van Belle, J. van Loon, E., Bouten, W., Buurma, L. 2006. A comparative analysis of the influence of weather on the flight altitudes of birds. *Bulletin of the American Meteorological Society* 87: 47-61.
6. Sierdsema, H. and van Loon, E. (*accepted*) Filling the gaps: using count survey data to predict bird density distribution patterns and estimate population sizes. *Turkish Journal of Zoology*.
7. Bouten, W., van Belle, J., Benabdelkader, A., Buurma, L., van Gasteren, H., de Hoon, A., Heuvelink, G. B. M., Foppen, R., van Reenen, G., Seijmonsbergen, H., Shamoun-Baranes, J. and Sierdsema, H. 2003. Towards an operational Bird Avoidance System: combining models and measurements. *Proceedings of the 26th International Bird Strike Committee*, pp. 19-31, Warsaw, Poland, 5-9 May.
8. Bouten, W. and Shamoun-Baranes, J. 2003. Towards a Bird Avoidance Model. NL-BAM report. Universiteit van Amsterdam.
9. Bouten, W., Shamoun-Baranes, J., and van Loon, E.E. 2004. Towards a Bird Avoidance System for increasing flight safety: the challenge of a 4D reconstruction of bird density over the Netherlands. NL-BAM report. Universiteit van Amsterdam.
10. Shamoun-Baranes, J. Bouten, W. van Belle, J. Buurma, L. and van Gasteren, H. 2005. Flight altitudes of birds. Bulletin of the Amercian Meteorological Society 86: 18-19 (invited summary).
11. Shamoun-Baranes, J. and van Loon, E. (*submitted*). Energetic influence on gull flight strategy selection. Journal of Experimental Biology.

12. Vrugt, J.A., van Belle, J., Bouten, W. (*accepted*) Pareto front analysis of flight time and energy use in long distance bird migration.

Appendix A1. List of available data sources for each of the primary and secondary NL-BAM species

* species were eliminated from NL-BAM

Scientific Name	*English Name*	*Primary species*	*Second. species*	*PTT*	*WAV*	*BSP*	*BMP*	*LSB*
Phalacrocorax carbo	Great Cormorant	Y		X	X			X
Ardea cinerea	Grey Heron	Y		X	X			X
Ciconia ciconia	White Stork		Y			X		X
Platalea leucorodia	Eurasian Spoonbill		Y		X			X
Cygnus olor	Mute Swan	Y		X	X		X	
Cygnus bewickii	Bewick's Swan		Y		X			
Cygnus cygnus	Whooper Swan		Y		X			
Anser serrirostris	Tundra Bean Goose	Y			X			
Anser brachyrhynchus	Pink-footed Goose	Y			X			
Anser albifrons	Greater White-fronted Goose	Y			X			
Anser anser	Greylag Goose	Y			X		X	
Branta canadensis ssp	canada goose		Y	X	X			
Branta leucopsis	Barnacle Goose	Y			X			
Branta bernicla ssp	brent goose		Y		X			
Alopochen aegyptiacus	Egyptian goose		*	X	X			
Tadorna tadorna	Common Shelduck		Y		X			
Mareca penelope	Eurasian Wigeon	Y			X			
Anas crecca	Common Teal		Y		X			
Anas platyrhynchos	Mallard	Y		X	X		X	
Anas acuta	Northern Pintail		Y		X			
Anas clypeata	Northern Shoveler		Y		X		X	
Aythya ferina	Common Pochard		Y		X		X	
Aythya fuligula	Tufted Duck		Y		X		X	
Circus cyaneus	Hen Harrier		Y	X	X			X
Accipiter gentilis	Northern Goshawk	Y		X			X	
Accipiter nisus	Eurasian Sparrowhawk		Y	X			X	
Buteo buteo	Common Buzzard	Y		X			X	
Falco tinnunculus	Common Kestrel	Y		X			X	
Falco subbuteo	Eurasian Hobby		Y	X			X	
Perdix perdix	Grey Partridge		Y	X			X	
Grus grus	Common Crane	Y				X		
Haematopus ostralegus	Eurasian Oystercatcher	Y		X	X		X	
Pluvialis apricaria	European Golden Plover	Y		X	X			
Vanellus vanellus	Northern Lapwing	Y		X	X		X	
Calidris canutus	Red Knot		Y		X			
Calidris alpina	Dunlin	Y			X			

Scientific Name	*English Name*	*Primary species*	*Second. species*	*PTT*	*WAV*	*BSP*	*BMP*	*LSB*
Gallinago gallinago	Common Snipe	Y		X	X		X	
Scolopax rusticola	Eurasian Woodcock		Y		X		X	
Limosa limosa	Black-tailed Godwit	Y		X	X		X	
Limosa lapponica	Bar-tailed Godwit	Y			X			
Numenius arquata	Eurasian Curlew	Y		X	X		X	
Tringa totanus	Common Redshank		Y	X	X		X	
Larus ridibundus	Black-headed Gull	Y		X	X			
Larus canus	Mew Gull	Y		X	X			
Larus graellsii	Lesser Black-backed Gull	Y			X			
Larus argentatus	European Herring Gull	Y			X			
Larus marinus	Great Black-backed Gull		Y		X			
Sterna hirundo	Common Tern		*		X			
Columba oenas	Stock Dove	Y		X			X	
Columba palumbus	Common Wood Pigeon	Y		X			X	
Columba domestica	Feral Pigeon		*	X			X	
Apus apus	Common Swift	Y		X			X	
Alauda arvensis	Eurasian Skylark		Y	X			X	
Hirundo rustica	Barn Swallow	Y		X			X	
Delichon urbica	Common House Martin	Y		X			X	X
Anthus pratensis	Meadow Pipit		Y	X			X	
Motacilla alba	White Wagtail		Y	X			X	
Turdus pilaris	Fieldfare	Y		X				
Turdus philomelos	Song Thrush	Y		X			X	
Turdus iliacus	Redwing	Y		X				
Corvus monedula	Western Jackdaw	Y		X			X	
Corvus frugilegus	Rook		Y	X				X
Corvus corone	Carrion Crow		Y	X			X	
Sturnus vulgaris	Common Starling	Y		X			X	
Fringilla coelebs	Common Chaffinch	Y		X			X	

Appendix A2. Descriptive species specific summary of accuracy of spatial distribution

Following are some species specific comments on irregularities noted after the original complete mapping procedure, including, where relevant, treatment of these irregularities.

*: after first analysis kriging was eliminated from mapping procedure.
(*) after first analysis kriging was eliminated from mapping of the WAV-data

720 Aalscholver Great Cormorant (*)
High numbers in ZO-Drenthe in all months. Very high numbers near Maastricht in April due to kriging. Therefore, kriging not used*. Data weights for April and August water bird count reduced.

1220 Blauwe Reiger Grey Heron
Probably overestimation of numbers in midden-Limburg: water bird counts have high numbers along the Meuse.

1340 Ooievaar White Stork
No structural problems.

1440 Lepelaar Eurasian Spoonbill
In general no structural problems. Numbers in the mainland dunes too high.

1520 Knobbelzwaan Mute Swan (*)
Kriging map of May is wrong*. BMP is added in May-August to improve inland distribution in the summer months. BMP-factor 1 is used because of overestimation of the breeding bird numbers.

*1530 Kleine Zwaan Bewick's Swan **
In general no structural problems. No reg-kriging maps available for all months*. Numbers in inland Noord-Brabant overestimated.

*1540 Wilde Zwaan Whooper Swan **
No structural problems.

*1574 Toendrarietgans Tundra Bean Goose **
No structural problems.

*1580 Kleine Rietgans Pink-footed Goose **
No structural problems. Slight overestimation of range: the species is almost entirely limited to a small area SW-Friesland.

*1590 Kolgans Greater White-fronted Goose **
No structural problems. However, regression-kriging maps are rather patchy.

*1610 Grauwe Gans Greylag Goose**

Very wrong in Zuid-Limburg and many other places. Regression maps are much better. BMP-data included to improve inland estimates in May-Aug. Data weight BMP set 0.5 because of overestimation regression model.

*1660 canadese gans Canada goose**
No structural problems. Distribution in summer probably too limited. Although breeding bird atlas estimates could be included to solve this problem, April & September BMP counts were included as with other ducks.

*1670 Brandgans Barnacle Goose**
Many kriging artefacts: probably mainly a distance problem. The regression is much better *, but overestimates the numbers in the southern part of Zeeland and around Groningen-city. In the future, the kriging-parameters have to be adjusted. Over estimation in Biesbosch-area. Species is absent in June-July: Dataweight set to 0 in June-July. Recent trend differs from trend in 97-01.

*1680 rotgans brent goose**
Over estimation in Biesbosch-area. Absent in June-July -: Dataweight set to 0 in June-July. Recent trend differs from trend in 97-01

1700 Nijlgans Egyptian Goose (*)
All maps show extreme numbers. This is due to extreme estimates from the regression predictions. A completely different approach is needed for this species. Therefore (currently) omitted.

1730 Bergeend Common Shelduck (*)
No structural problems.

1790 Smient Eurasian Wigeon (*)
No structural problems. Kriging extends distribution too far into neighbouring region along IJssel.

1840 Wintertaling Common Teal (*)
No structural problems.

1860 Wilde Eend Mallard (*)
Large kriging artefacts in June*. Only regression predictions are used.

*1890 Pijlstaart Northern Pintail **
In general no structural problems, but inland numbers too high.

1940 Slobeend Northern Shoveler (*)
In general no structural problems. Kriging artefact near Bergen op Zoom in May.

1980 Tafeleend Common Pochard (*)
In general no structural problems, but a number of Kriging artefacts in winter, especially around Utrecht.

2030 Kuifeend Tufted Duck (*)

Large Kriging artefacts in June in Zeeland due to extreme kriging output. In other winter months ‘kriging oil spills’ mainly in the east. Therefore only the regression predictions are used*.

2610 Blauwe Kiekendief Hen Harrier
No structural problems.

2670 Havik Northern Goshawk
BMP numbers high as compared to PTT. BMP-estimates high as compared to national estimate. BMP-factor set to 1

2690 Sperwer Eurasian Sparrowhawk
In general no structural problems. August appears to be underestimated. Difficult to improve easily.

2870 Buizerd Common Buzzard
November and February underestimated due to recent expansions. Therefore PTT12 is also used for these periods.

3040 Torenvalk Common Kestrel
BMP numbers low as compared to PTT, but BMP-estimates equal to national estimates. Data weight of August decreased because of long term decline. Probably overestimation of breeding bird numbers in Zuid-Limburg

3100 Boomvalk Eurasian Hobby
No structural problems.

3670 Patrijs Grey Partridge
No structural problems.

4330 Kraanvogel Common Crane
No structural problems.

4500 Scholekster Eurasian Oystercatcher (*)
Large Kriging artefact in August in the Delta. Kriging map of WAV8 is rubbish. Kriging produces too many zero’s. Therefore only regression prediction maps are used: these overestimate the numbers in winter in the north of Friesland and Groningen.

4850 Goudplevier European Golden Plover (*)
No structural problems.

4930 Kievit Northern Lapwing (*)
Large kriging artefacts in several months, especially May & August. Kriging not used. BMP underestimated as compared to other data-sources. BMP-estimates are equal to national estimate, but national estimate is likely underestimated (like in Black Tailed Godwit). Therefore BMP-factor is set to 3.

*4960 Kanoet Red Knot **
In general, no structural problems. Bird should be absent near Rotterdam.

*5120 Bonte Strandloper Dunlin **
In general, no structural problems. Bird should be absent near Rotterdam.

5190 Watersnip Common Snipe (*)
In general, no structural problems. Maybe underestimate in February.

5290 Houtsnip Eurasian Woodcock
In general, no structural problems.

5320 Grutto Black-tailed Godwit (*)
Numbers in July-August are too high and species is too widespread. Kriging introduces strange artefacts, while prediction map alone is OK in general. Kriging maps not used.

*5340 Rosse Grutto Bar-tailed Godwit **
In general, no structural problems. Bird should be absent near Rotterdam.

5410 Wulp Eurasian Curlew (*)
In general, no structural problems.

5460 Tureluur Common Redshank (*)
In general, no structural problems. Possibly numbers are too high in northern areas of Friesland and Groningen outside Wadden.

5820 Kokmeeuw Black-headed Gull (*)
Absent from Twente-Achterhoek due to masking of waterbird counts. PTT counts of February and August are used to fill in this gap. Kriging doesn't appear to improve the counts and underestimates spring numbers. Only the regression maps are used because they look reliable and do not show any artefacts.

5900 Stormmeeuw Mew Gull (*)
In general, no structural problems. Some kriging-artefacts in July.

5910 Kleine Mantelmeeuw Lesser Black-backed Gull (*)
Many large kriging artefacts. Kriging maps are not useful. Distribution in late spring and summer-distribution underestimated: the species is quite common inland in this period. Only regression maps are used.

5920 Zilvermeeuw European Herring Gull (*)
Large kriging artefacts in August. But rest of maps are alright in general. Kriging not used for August, but should be improved.

6000 Grote Mantelmeeuw Great Black-backed Gull (*)
Very large kriging artefacts. Regression maps used. TOY-weight set to 0.9 to introduce summer absence. Probably overestimation of bird numbers in late spring and summer.

6150 Visdief Common Tern (*)
All maps show extreme numbers. This is due to extreme estimates from the regression predictions. A completely different approach is needed for this species. Therefore, (currently) omitted.

6680 Holenduif Stock Dove
In general, no structural problems. Probably too low numbers in August. Data of November used for this period.

6700 Houtduif Common Wood Pigeon
In general, no structural problems. Kriging of the BMP-data returns too many zero's. Kriging turned off for the period March-August.

7950 Gierzwaluw Common Swift
No structural problems

9760 Veldleeuwerik Eurasian Skylark
No structural problems. Birds are very elusive in August.

9920 Boerenzwaluw Barn Swallow
Problem in scaling between BMP and PTT-counts. Breeding bird numbers too low as compared to August-numbers: overestimation of August-numbers? BMP probably underestimates the numbers. BMP-factor 7 is used to correct underestimation of the BMP-numbers.

10010 Huiszwaluw Common House Martin
In general, no structural problems. Kriging artefacts in Zeeland and Achterhoek.

10110 Graspieper Meadow Pipit
No structural problems

10201 Witte Kwikstaart White Wagtail
No structural problems

11980 Kramsvogel Fieldfare
No structural problems

12000 Zanglijster Song Thrush
Kriging exaggerates the differences in the BMP-maps, therefore kriging is not used. Strange high numbers in oost-Drenthe in autumn. Underestimation of numbers in September - October.

12010 Koperwiek Redwing
No structural problems

15600 Kauw Western Jackdaw
In general, no structural problems. Slight underestimation BMP as compared to PTT and national estimates. BMP-factor changed to 3

15630 Roek Rook
No structural problems

15671 Zwarte Kraai Carrion Crow
Difficult species. PTT appears to overestimate the numbers. PTT-data from November and August doesn't show recent expansion in the west: PTT12 is also used in maps of October -

March. Kriging doesn't really improve the maps and exaggerates differences. In order to scale BMP and PTT equally BMP-factor is set to 4.

15820 Spreeuw Common Starling
Underestimation of BMP-numbers as compared to national estimates and PTT-maps. BMP-factor set to 5. Kriging exaggerates local differences in numbers leading to many zero's: therefore omitted.

16360 Vink Common Chaffinch
Winter numbers (PTT) too low as compared with breeding numbers (BMP). Kriging of BMP-data delivers too many zeros. PTT kriging is OK. For practical purposes the BMP numbers are downscaled, but ideally the PTT-numbers should be upscaled. BMP-factor is set to 1.

20030 Stadsduif Feral Pigeon
Not enough data available to produce reliable abundance maps. Species (currently) excluded.

Appendix A3. Descriptive species specific summary of accuracy of total numbers for spatial distribution models

Following are some species specific comments on irregularities noted after the final complete mapping procedure. Code used in table is as follows: identification of numbers too low (-) or too high (+) per seasonal period. +++/--- indicates much to high/low but unknown how much. Remarks for each species follow in the row below the seasonal pattern description.

Species		Period																							
Eur. code	name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
720	Great Cormorant	---	---	---	---																		---	---	---
		Winter numbers don't match WAVO counts. Seasonal pattern not cfm WAVO																							
1220	Grey Heron	-2	-3	-5	-5												-3	-1	-1	-1	-1	-2	-2	-2	-2
		Seasonal pattern of WAVO is opposite of TOY adj maps																							
1440	Spoonbill															+++									
		Nice pattern																							
1520	Mute Swan							---	---	---	---	---	---	---	---	---	---								
		BMP: 12.000 exx, not included in maps, including 15.000 from WAVO																							
1530	Bewick's Swan																								
		Nice, numbers a bit to high																							
1540	Wooper Swan																								
		OK																							
1574	Tundra Bean Goose																								
		No PTT project included ?																							
1580	Pink-footed Goose																					5	5		
		Only November counts much too high																							
1590	Greater White-Fronted Goose																								
		BMP project lacking (500 exx)																							
1610	Greylag Goose							---	---	---	---	---	---	---	---	---	---								
		BMP project lacking (20.000 exx)																							
1660	Canada Goose							---	---	---	---	---	---	---	---	---	---					+++	+++		

BMP project missing (2500 exx)

1670 Barnacle Goose

WAVO May-August are missing. BMP is missing (thousands of birds)

1680 Brent Goose

Low numbers, but OK. Biesbosch ??

1790 Eurasian Wigeon

Very nice distribution and estimated numbers!! Congratulations with this one

1840 Common Teal --- --- --- --- --- ---

Breeding numbers not included (5000)

1860 Mallard ---

BMP not included (800000)

1890 Pintail

OK

1940 Shoveler --- --- --- --- --- --- --- --- ---

BMP not included (15000)

1980 Pochard --- --- --- --- --- --- --- --- --- --- --- --- --- ---

BMP not included (4000) low numbers in autumn?

2030 Tufted Duck --- --- --- --- --- ---

BMP not included (35000)

2610 Hen Harrier

OK

2670 Goshawk

Numbers rather low

2690 Sparrowhawk ---

BMP not included (9000)

2870 Buzzard --- --- --- --- --- ---

Nice, but with some strange errors

3040 Kestrel --- --- --- --- --- --- --- ---

BMP not included (12000) Overall numbers are low

3100 Hobby --- --- --- --- ---

BMP not included (2000), why is this species included anyway

3670 Grey Partridge --- --- --- --- --- --- --- --- --- ---

BMP not included (20000)

4500	Oystercatcher	-3	-3	-3	-3	-3	-5	-5	-5	-5	-5	-5	-5	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
		BMP 200000exx, winter: 200000 exx, seasonal pattern not cfm WAVO counts																							
4850	Golden Plover																								
		OK, nice!!																							
4930	Lapwing					-2	-3	-3	-3	-3	-3	-3	-3	-2	-2	-2	-2	-2							
		Nice autumn numbers, OK. BMP by far too low numbers																							
4960	Red Knot																								
		OK, low winter numbers, but species is declining																							
5120	Dunlin	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
		OK																							
5190	Common Snipe															---	---	---	---	---	---	---	---	---	
		OK																							
5290	Woodcock						-2	-2	-2	-2	-2	-2	-2	-2											
		BMP: from pairs to numbers.																							
5320	Black-tailed Godwit							-2	-2	-2	-2	-2	-2	-2											
		BMP numbers are low due toy of period 6 All numbers are lowered by this factor																							
5340	Bar-tailed Godwit	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		Seasonal pattern not according WAVO counts. Max numbers should exceed 100000 in period 9+10																							
5410	Curlew	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		BMP not included well in periods 5-13. Max winter numbers should exceed 125000																							
5460	Redshank							-2	-3	-3	-3	-3	-3	-2											
		Difficult species, but max of WAVO + BMP counts per square km will give a better solution. BMP not well included: 45000																							
5820	Black-headed Gull																								
		BMP not included (colonial breeder)																							
5900	Mew Gull						+++																		
		Period 6 is not so high in WAVO counts																							
5910	Lesser black-backed gull																								
		Max of WAVO + BMP colonial breeder will give better solutions																							
5920	Herring Gull																								
		Numbers should be more similar over the year. Winter numbers > 100000																							

6000	Great black-backed gull																								
		OK																							
6680	Stock Dove			---	---		-2	-2	-2	-2	-2	-2	-2	-2	---	---	---	---	---	---	---	---	---		
		BMP: pairs to numbers, period 3-4,14-18 errors																							
6700	Wood Pigeon						-2	-2	-2	-2	-2	-2	-2	-2	---	---	---	---							
		BMP: 900000 exx !! Period 14-17 totally wrong																							
7950	Swift									-3	-3	-3	-3	-3	-3	-3									
		BMP: 90000 exx. Difficult to add the whole Netherlands																							
9760	Skylark														---	---	---	---	---						
		OK																							
9920	Barn Swallow							---	---	---	---	---	---	---	---	---	---	---	---						
		BMP: 250000 exx MUCH TO LOW																							
10010	House Martin																								
		OK																							
10110	Meadow Pipit		---	---	---												---	---	---	---	---	---	---	---	
		Autumn and winter tens of thousands of birds																							
10201	White Wagtail																---	---	---	---	---	---	---	---	---
		All birds missing																							
11980	Fieldfare	+++																				---			
		Period 1-5 strange changes in number																							
12000	Song Thrush	---	---	---	---												---	---	---	---	---	---	---	---	---
		Non-breeding birds not included??																							
12010	Redwing			---	---	---	---	---												---	---	---	---		
		Migration in Spring and Autumn not included																							
15600	Jackdaw														---	---	---	---							
		BMP distribution difficult to compare with breeding atlas. Numbers OK (BMP)																							
15630	Rook																								
		OK, numbers may be a little bit too high																							
15671	Carrion Crow																								
		Large differences in numbers between breeding and non-breeding maps. Strange for a non-migratory bird! (BMP: 200000)																							
15820	Starling	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		BMP: 1500000-2000000 exx. Also in non breeding season. Strange (opposite) distribution between breeding and non-breeding seasons.																							
16360	Chaffinch	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		BMP: 1.3-1.5 million birds. No autumn migration?? (Millions of birds!!).																							

Appendix A4. Blank example of expert interview form

Expert: …. …. … … Species: … …

I. Birds present in the Netherlands (not the migrating birds that only fly OVER the Netherlands)

Figure 1. Draw relative abundance for the period(s) that this species is present in the Netherlands.
Maximum value for this species = 1

Keep it as simple as possible!!
Preferably stepwise changes and (very) limited number of levels.

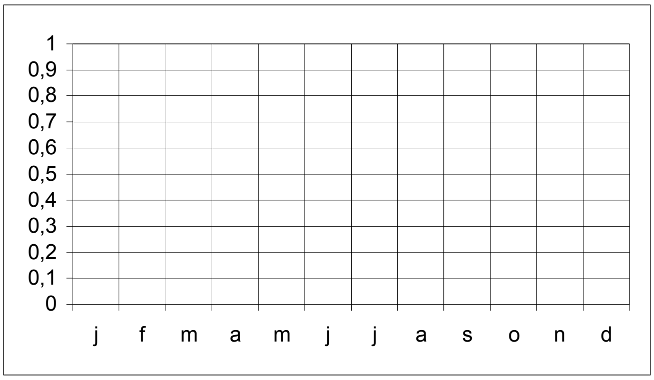
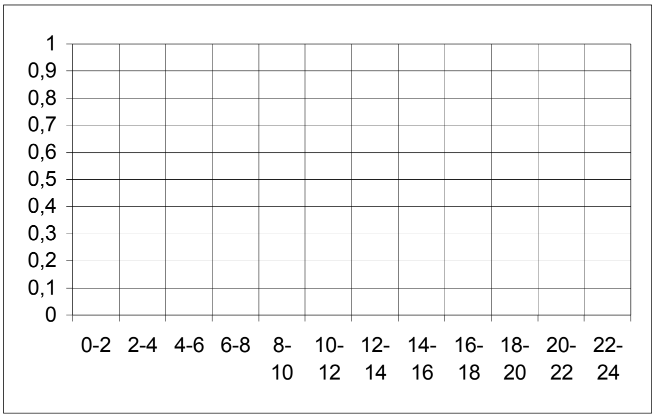


Figure 2. Which hours of the day is this species active (in the air).
Again keep it as simple as possible (0<activity<1)!!

If you really need to redraw this figure for different periods in the year, then use different colors in the graph.



How would you distribute all birds of this species over the various air layers.

Use one colum (A-H) for each combination of fig 1&2 $\neq$ 0 that you really need.

	A	B	C	D	E	F	G	H
>1000								
300-1000								
100-300								
30-100								
0-30								

For which days/periods can Henk (easily) produce maps:… … …

Continue on next page:

Expert: …. …. … …   Species: … … …

II. Migrating birds passing over the Netherlands (not staying for longer time (< few days).

Which are the migration periods (length and time)

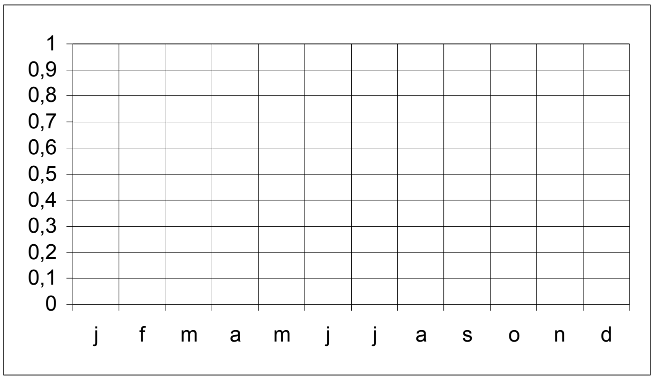
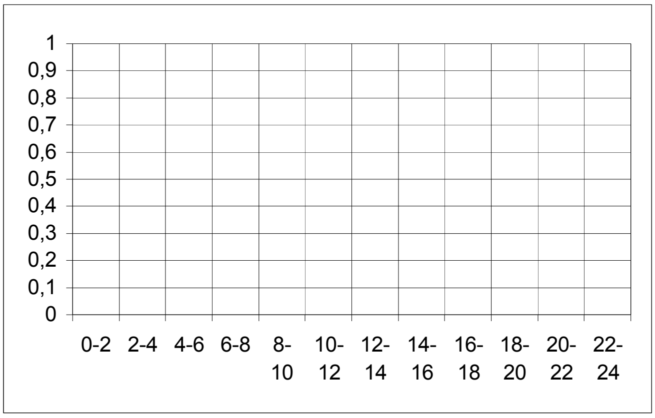


Figure 2. Which hours of the day/night is this species migrating. Again keep it as simple as possible (0-1)!!
If you really need to redraw this figure for different periods (spring/autumn), then use different colors in the graph.



How would you distribute all migrating birds of this species over the various air layers.

Use one colum (A-H) for each combination of fig 1&2 ≠ 0 that you really need.

	A	B	C	D	E	F	G	H
>1000								
300-1000								
100-300								
30-100								
0-30								

How many birds pass each season? Spring: .. .. …   Autumn … . .. …

Species specific comments: