Understanding avian collision rate modelling and application at the population level

Aonghais Cook
British Trust for Ornithology (BTO)

Mark Collier
Bureau Waardenburg (Buwa)

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Introduction to talk

BTO and Bureau Waardenburg

Birds and wind energy
Counting collisions
Why collision rate modelling

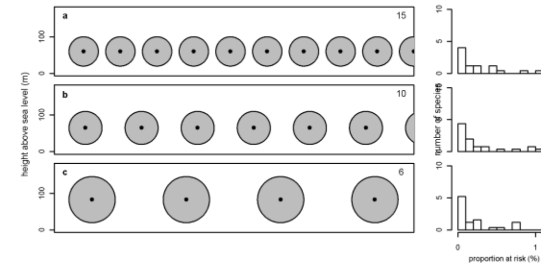
Overview of different models
Band model
Sensitivities and knowledge gaps

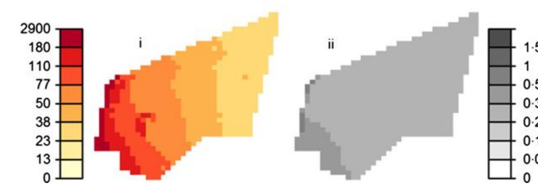
Results in the population context

How are outputs used by decision makers?

British Trust for Ornithology

- Independent & **IMPARTIAL** research organisation
- Provide advice to regulators & governmental advisors
- Also do work for Industry
- Key projects
  - Strategic Ornithological Support Services (SOSS)
  - Dogger Bank EIA
  - Seabird tagging to understand movements in & around offshore wind farms
  - Key reviews of survey methodology, seabird flight height & avoidance behaviour, collision risk modelling methodology, post-consent monitoring
- Ensure that decisions are based on the “Best available evidence”





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Mark Collier

- Ecological research and consultancy, founded in 1979.
- 75 staff, specialising in marine and aquatic ecology, nature and landscape, bird ecology.
- National and international projects – advise Governments, regulators and industry.
- Independent and objective approach. Creative and innovative solutions with a high level of practicality.

Wind energy and birds since 1992.

- Effect studies, EIAs, AAs, advice, monitoring, research, planning research and monitoring programmes, etc...
- Radar systems (mobile and automated)
- Remote technologies
- First Dutch offshore wind farms, gas platform 75 km from the shore, CRM for NL and UK round 3 sites, onshore wind.

Combining practical knowledge with theoretical techniques.

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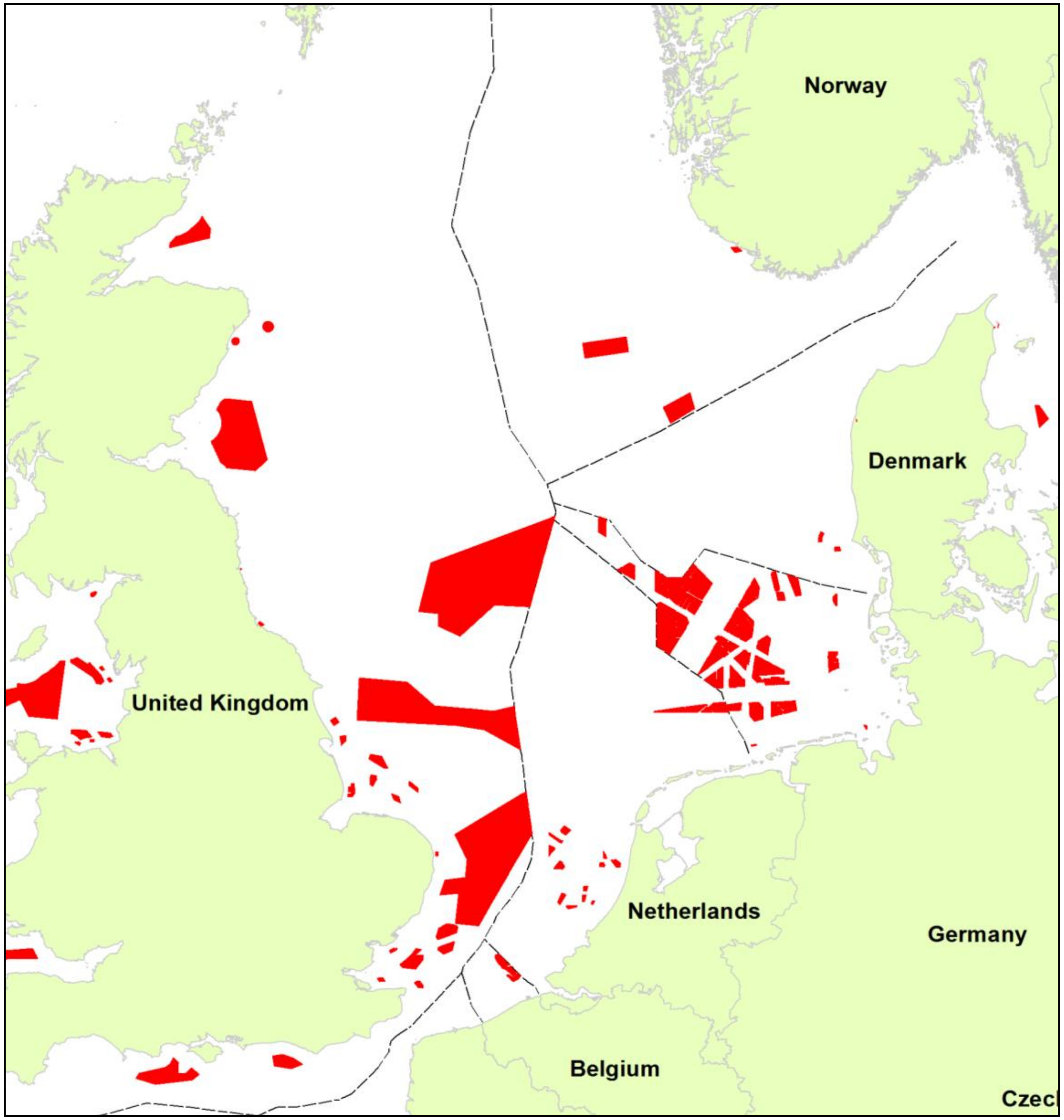
Introduction to BTO & Bureau Waardenburg



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Strategic Ornithological Support Services for the UK offshore wind industry (SOSS)

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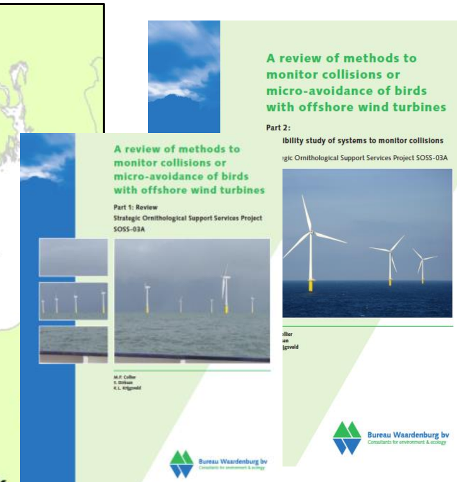
SOSS Steering Group

We would like to thank all SOSS steering group members for their valuable contributions to SOSS work. The steering group was made up of representatives of regulators, advisory bodies, and offshore wind farm developers, as well as the SOSS Secretariat. Some offshore wind farm developers chose to nominate consultants to attend in their place. Steering group members guided the identification and prioritisation of SOSS work, and advised on the development of scopes of work and project outputs.

Organisation	Role
BTO	SOSS Secretariat partner
The Crown Estate	SOSS Secretariat partner
Bureau Waardenburg	SOSS Secretariat partner




IMCC3 • 14-18 August, 2014 • Glasgow, Scotland

International Marine Conservation Congress

SY56. SYMPOSIUM:
INTERACTIONS BETWEEN BIRDS AND WIND TURBINES: UNDERSTANDING COLLISION RISKS IN THE MARINE ENVIRONMENT

DOCHART B ROOM
Saturday, 16 August, 8:30 to 10:30

ORGANIZER(S):
Liz Humphreys, *British Trust for Ornithology*; **Ian Davies**, *Marine Scotland*; **Sjoerd Dirksen**, *Bureau Waardenburg*; **Lucy Wright**, *British Trust for Ornithology*; **Aonghais Cook**, *British Trust for Ornithology*; **Karen Krijgsveld**, *Bureau Waardenburg*; **Ruben Fijn**, *Bureau Waardenburg*

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Birds and wind energy

Displacement of birds to other areas

Habitat loss

- Mostly limited to specific locations/species.
- On land and relatively small area (footprint of turbines and related infrastructure).

Disturbance of foraging/resting birds

- Mostly limited to specific locations/species.
- e.g. Bewick's swans showed preference to forage further from turbines early in season then moved closer to turbines (Fijn et al. 2012).
- Increasing importance with increase in wind farms (cumulative effects).

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Fijn, R.C., Krijgsveld, K.L., Tijsen, W., Prinsen, H.A.M. & Dirksen, S. 2012. Habitat use, disturbance and collision risks for Bewick's swans *Cygnus columbianus bewick*kii wintering near a wind farm in the Netherlands. Wildfowl 62: 97-116.
Top photo: Zeeland Ait/Bureau Waardenburg

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Birds and wind energy

Displacement of birds to other areas

Barrier effects (disturbance of flight paths / effective habitat loss)

- Mostly limited to specific locations/species (e.g. breeding colony).
- e.g. migrating eiders travelled only 500m further during their 1400km migration (Masden *et al*. 2009).
- Increasing importance with increase in wind farms (cumulative effects).

May influence survival indirectly

Increasing importance with more wind farms - cumulative effects

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Masden, E. A., Haydon, D. T., Fox, A. D., Furness, R. W., Bullman, R. & Desholm, M. 2009. Barriers to movement: impacts of wind farms on migrating birds. – ICES Journal of Marine Science, 66: 746–753.
Photo: Zeeland Ait/Bureau Waardenburg

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Birds and wind energy

Collisions of flying birds

Direct mortality – attracted most attention

Current estimates of 0.05 - 30 (up to 60) collisions per turbine per year, fewer offshore (Krijgsveld et al. 2009).

Altamont Pass, Ca. = 5,400 turbines
Estimated collisions annually:
>2,700 – 11,500 birds
>1,100 – 2,300 raptors
(Smallwood & Thelander, 2008)

Variation due to: flight intensities, location, time of year or day, species…

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Krijgsveld, K.L., Akershoek, K., Schenk, F., Dijk F. & Dirksen, S. 2009. Collision risk of birds with modern large wind turbines. Ardea 97(3): 357-366.

Smallwood, K.S. & Thelander, C.G. 2008. Bird mortality in Altamont Pass Wind Resource Area California. J. Wildl. Manage.72: 215–213.

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Counting collisions

Victim searches

Daily to weekly searches.

Corrections needed for search efficiency and predator removal.

Use of dogs.

+ fulfil monitoring obligations
+ build on knowledge of bird-turbine interactions
+ combined with (radar) studies on flight patterns

- labour intensive (larger wind farms)
- access to location
- not all habitats
- not offshore
- not pre-construction

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Counting collisions offshore

Observations - too few collisions!

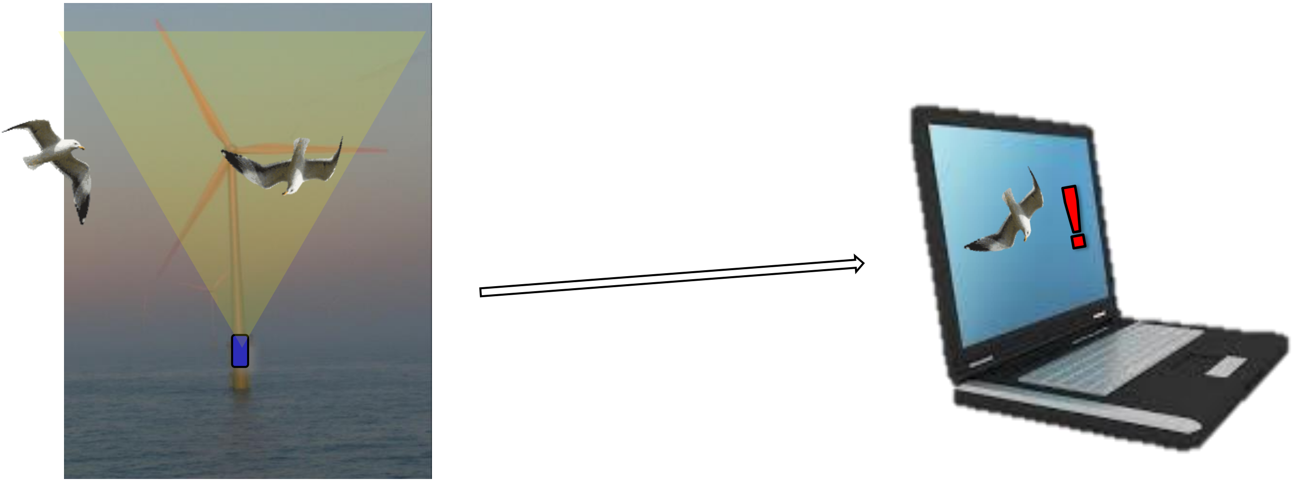
- one every two weeks to 20 years!
- at night or poor weather

Automatic registration system

Reviewed in Collier *et al*. (2011 and 2012)

http://www.bto.org/science/wetland-and-marine/soss/projects

Camera and microphones



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Collier, M.P., S. Dirksen & K.L. Krijgsveld, 2011. A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines. Part 1: Review. Strategic Ornithological Support Services Project SOSS-03A. Rapport 11-078. Bureau Waardenburg, Culemborg.

Collier, M.P., S. Dirksen & K.L. Krijgsveld, 2012. A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines: Part 2: Feasibility study of systems to monitor collisions. Strategic Ornithological Support Services Project SOSS-03A. Rapport 11-215. Bureau Waardenburg, Culemborg.

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Counting collisions offshore

Observations - too few collisions!
- one every two weeks to 20 years!
- at night or poor weather

Automatic registration system

Reviewed in Collier *et al*. (2011 and 2012)

http://www.bto.org/science/wetland-and-marine/soss/projects

Camera and microphones

Several systems in development:

WT Bird in use offshore - camera to be tested (Bureau Waardenburg)

DT Bird in use – no detection trigger

Still requires development and validation

For post-construction monitoring

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Collier, M.P., S. Dirksen & K.L. Krijgsveld, 2011. A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines. Part 1: Review. Strategic Ornithological Support Services Project SOSS-03A. Rapport 11-078. Bureau Waardenburg, Culemborg.

Collier, M.P., S. Dirksen & K.L. Krijgsveld, 2012. A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines: Part 2: Feasibility study of systems to monitor collisions. Strategic Ornithological Support Services Project SOSS-03A. Rapport 11-215. Bureau Waardenburg, Culemborg.

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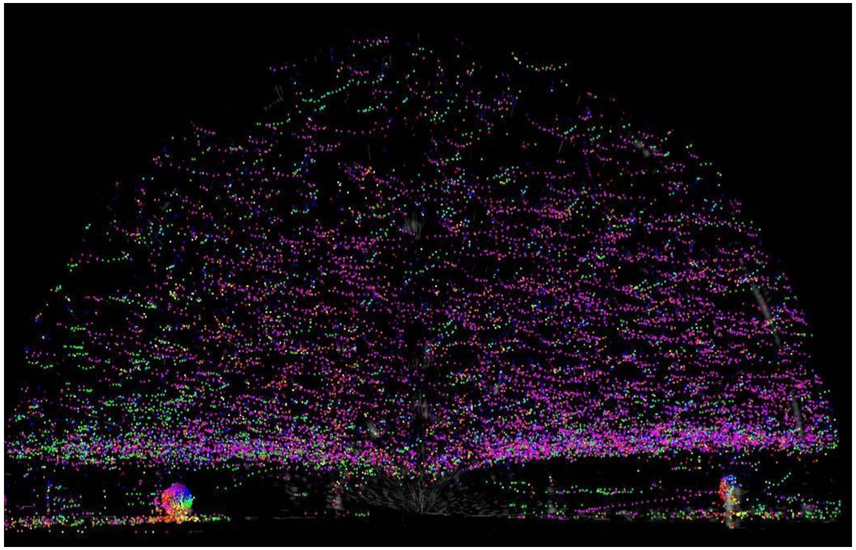
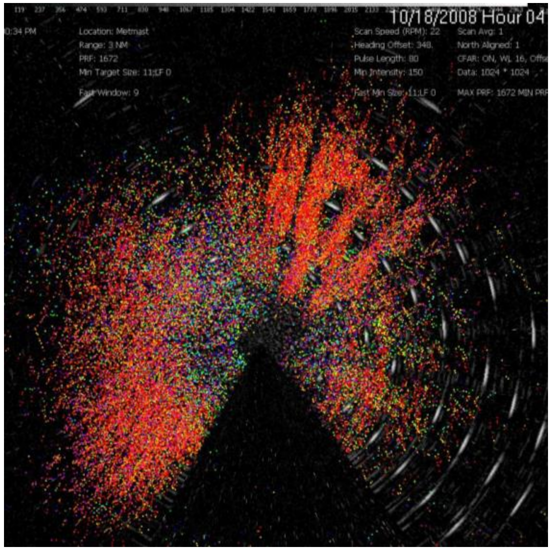
Why collision rate modelling

Number of birds x Collision risk = Number of collisions





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Why collision rate modelling

Estimate effects:

- prior to construction to inform planning.
- for inaccessible locations.
- on vulnerable species.

Commonly applied models:

Troost (1, 2 & 3) - Empirical and Theoretical based.
- Developed for Dutch offshore situation.

Band (SOSS Band) - The standard in many countries.
- key model for offshore.

Flux Collision Model - Empirical based.
- Based on collision data, less reliant on avoidance rates.
- *Kleyheeg-Hartman et al. In prep*.

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Collision risk modelling

- CRM used to predict the likely number of bird collisions with a wind turbine/farm
- Bird and turbine inputs (no uncertainty/variation)
- Core usually probability of collision from a single transit
- Based on probability of a turbine blade occupying same space as bird during the time that bird takes to pass through rotor
- One transit to many, using survey data
- Add element of bird behaviour i.e. avoidance
- Output is usually a single estimated number of collisions

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Collision risk modelling

Model name and reference	Based on…	Number of turbines	Tower included	Wind speed/direction included	Oblique angles of approach	Individual or population	Onshore or offshore example	Stochastic or deterministic	Model output
Band (Band 2000; Band 2012)	-	Multiple	N	N	N	Population	Offshore	D	# birds colliding
Tucker (1996)	-	Single	N	N	N	Individual	-	D	Probability of collision
Biosis (Smales *et al.* 2013)	-	Multiple	Y	N	Y	Population	Onshore	D	# birds colliding
Podolsky (Podolsky 2008)	-	Multiple	Y	N	Y	Individual	Onshore	D	Probability of collision
McAdam (McAdam 2005)	Band	Single	N	Speed & direction	Y	Individual	Offshore	S	Probability of collision
Desholm (Desholm & Kahlert 2007)	-	Multiple	N	Direction	N	Population	Offshore	S	# birds colliding
Eichhorn (Eichhorn *et al.* 2012)	Band	Single	N	N	N	Individual	Onshore	S	Mortality rate
Holmstrom (Holmstrom *et al.* 2011)	Tucker	Single	N	Speed & direction	Y	Individual	-	D	Probability of collision
Bolker (Bolker, Hatch & Zara 2014)	-	Multiple	N	N	Y	Individual	Onshore	D	Probability of collision
USFWS (U.S. Fish and Wildlife Service 2013)	-	Multiple	Not specified	N	N	Population	Onshore	S	Number of fatalities

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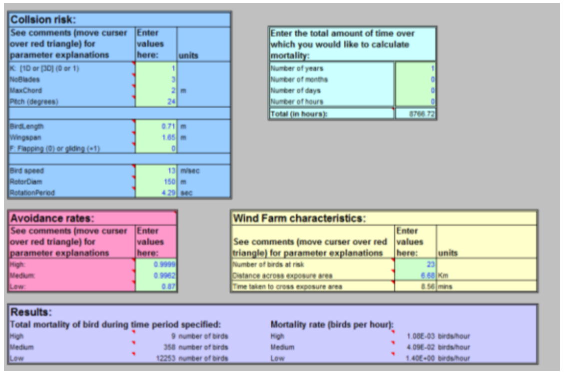
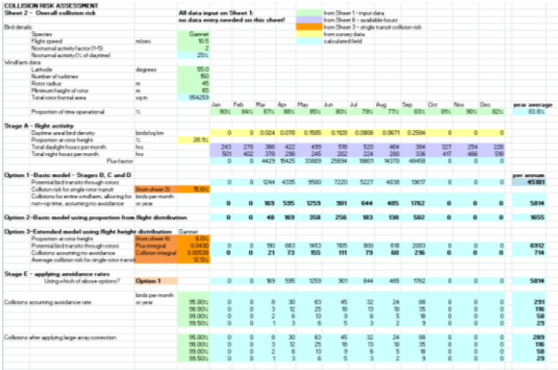
Band Model

- UK Most widely used is Band
- Developed by SNH for use with Islay Onshore wind farm
- Subsequently adapted for offshore environment
- Key Changes
  - Monthly estimates
  - Density rather than count
  - Different options for incorporating % birds at rotor height





Sensitivities

- Avoidance Rate
- Flight Height
- Flight Speed

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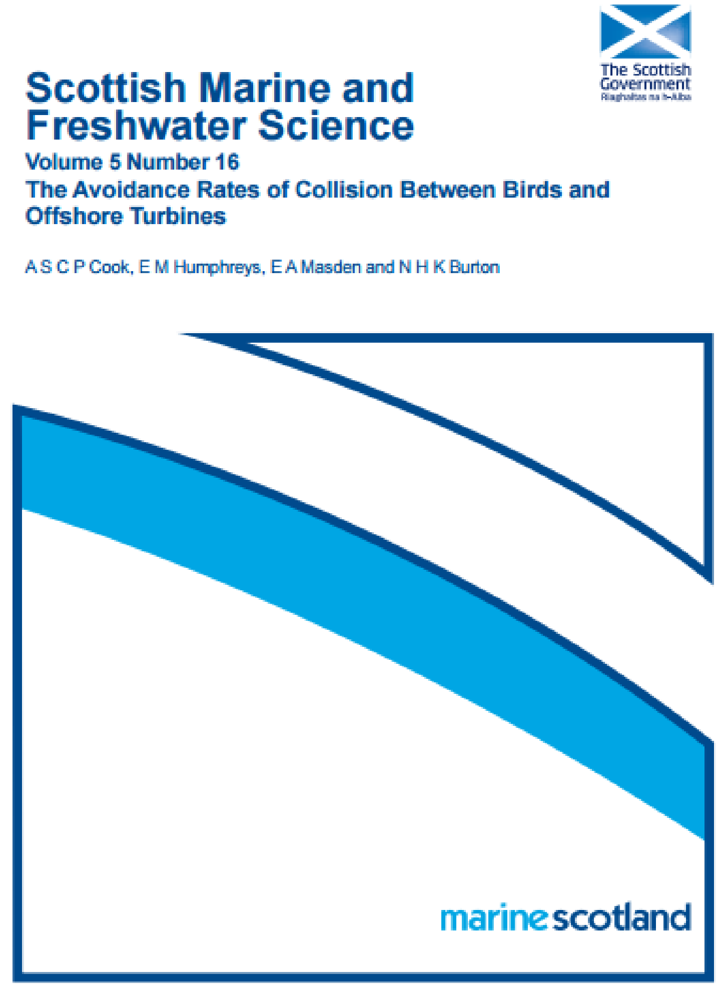
Avoidance Rate

- Identified by Chamberlain *et al.* (2006) as the key parameter in model
  - 10% change in avoidance rate = >2500 % increase in predicted collisions
- Despite this, evidence base remains weak
- BTO Commissioned by MSS to undertake major review in relation to offshore wind farms


The Scottish Government
Riaghaltas na h-Alba

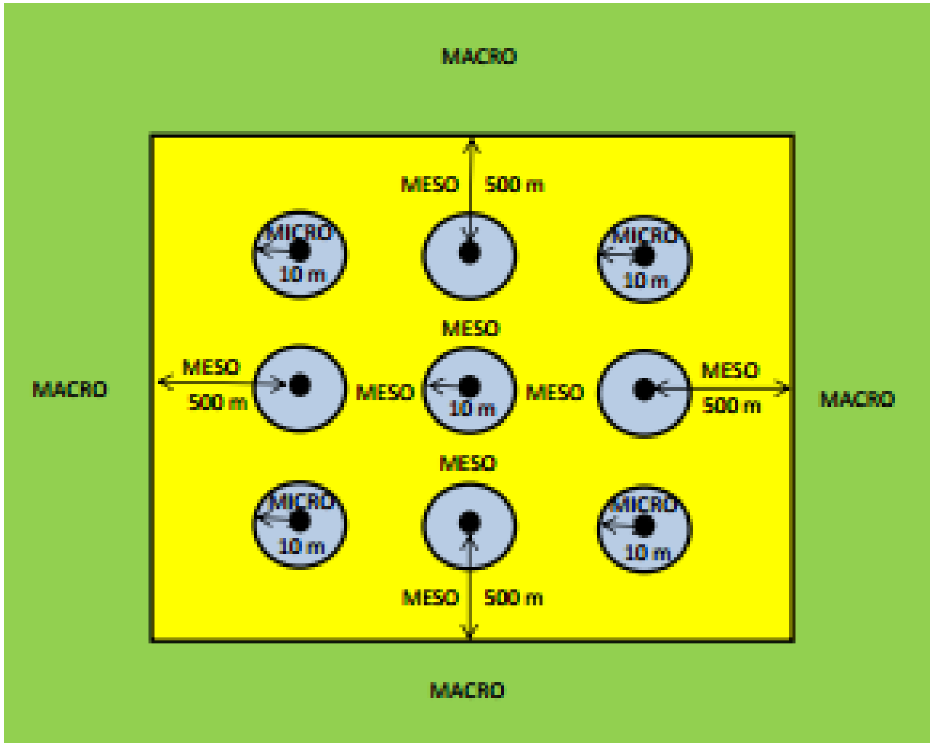
Scottish Marine and Freshwater Science
Volume 5 Number 16
The Avoidance Rates of Collision Between Birds and Offshore Turbines

A S C P Cook, E M Humphreys, E A Masden and N H K Burton

marine scotland

Avoidance Rate

- Can be estimated in two ways
  - Direct measurement (i.e. radar, visual observation etc.)
  - Comparing recorded collisions to number of birds present
- First challenge, define spatial scales
  - Macro
  - Meso
  - Micro



Macro

- Draw on evidence from studies of barrier effects/displacement
- Very species specific
- Gannet strong macro-response
- Gulls unclear evidence of attraction & avoidance

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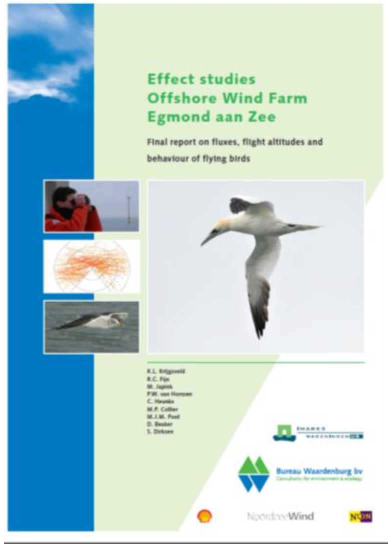
Meso/Micro

- Very little evidence for meso/micro
- Key study OWEZ radar + visual observations
- Draw on onshore studies of collisions
  - Estimated collision rate
  - Estimated flux rate
- 20 sites UK, Europe & US
- Mostly gulls, some terns



Avoidance Rate = 1 – (observed collisions / probability of collision x flux)

Total Avoidance

- Combined meso/micro ~99-99.5% for gulls
- No macro, so total avoidance = 99%
- No evidence base for gannet
- High meso/micro rate for gulls + high macro avoidance suggests total avoidance unlikely to be lower than that for gulls

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Flight Heights

- Recent analysis (Masden 2015) shows % birds at risk height AS IMPORTANT as avoidance rate
- Typically estimated from boat surveys
- 3 key problems
  - Estimates reflect height above MEAN SEA-LEVEL, turbines must be >22 m above HIGHEST ASTRONOMIC TIDE
  - Restrictive – cannot assess impact of raising/lowering turbine height
  - No measure of uncertainty – single value for each species
- Also analytical issues

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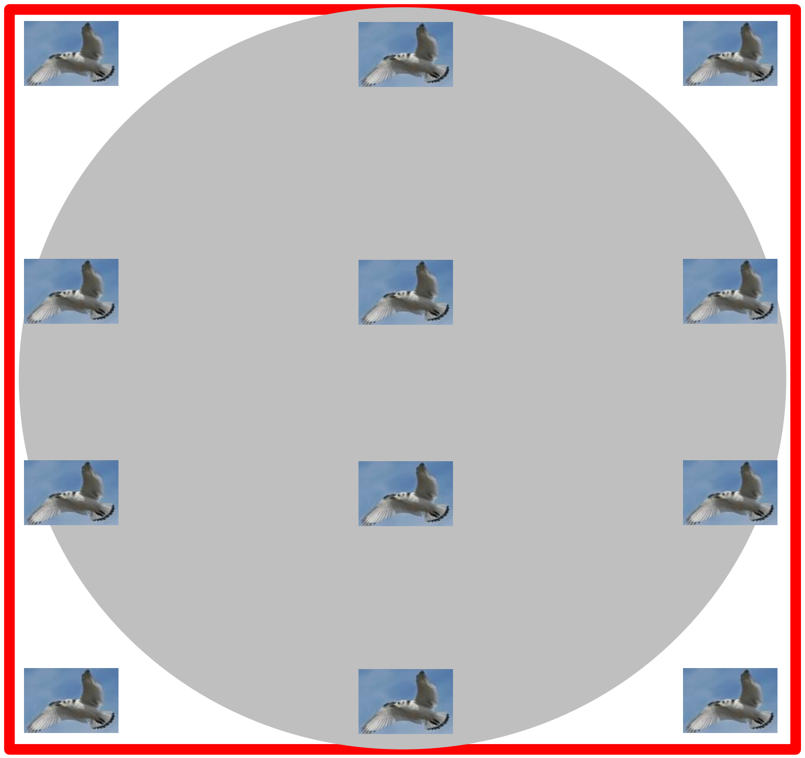
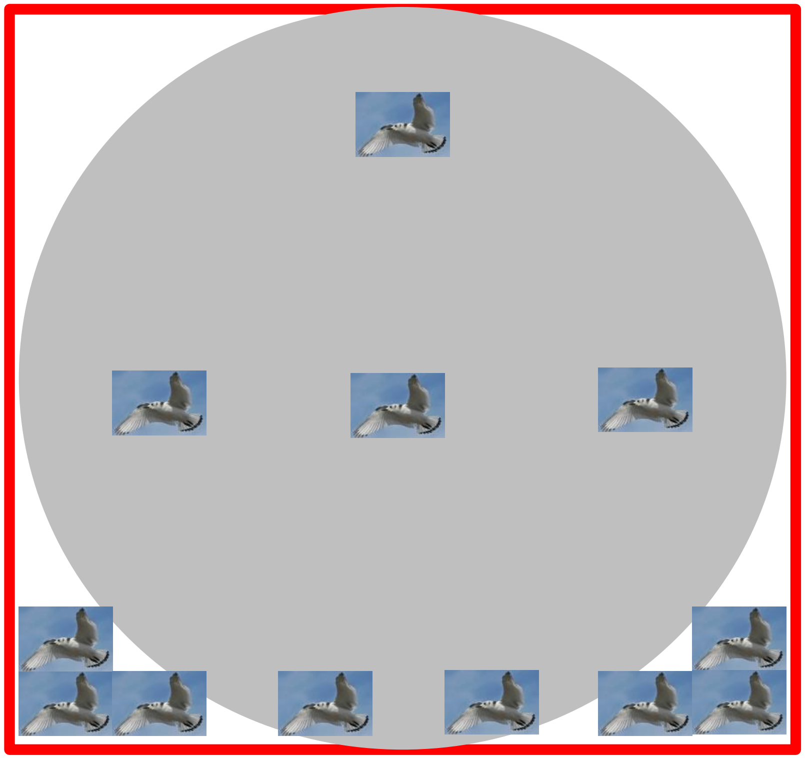
Flight Heights





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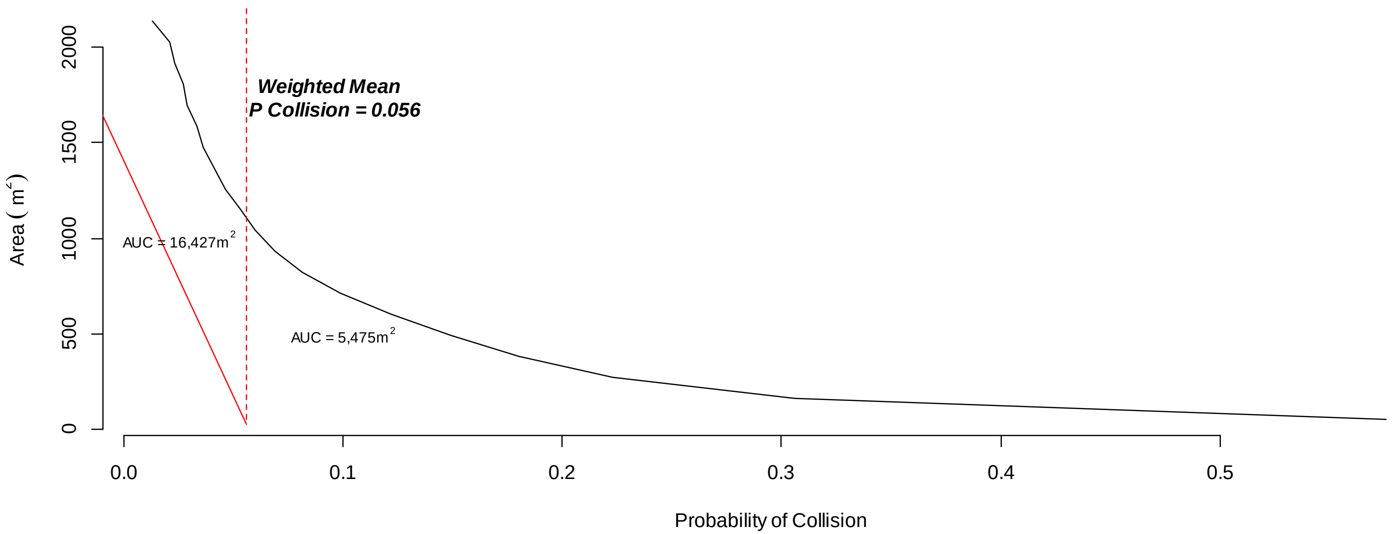
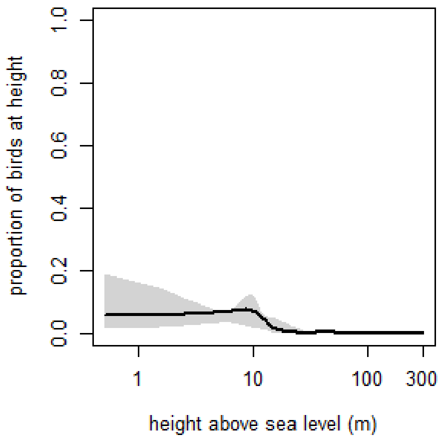
Flight Heights



Flight Heights

- Can combine boat data to produce continuous distributions
- “Extended” or “Option 3” Band model
- On going work to produce similar distributions from Digital Aerial Survey data



Flight Speed

- Largely ignored
- Goes into model twice
  - Estimate of flux rate
  - Estimate of probability of collision
- 2 standard sources

OPEN ACCESS Freely available online
PLoS BIOLOGY

Flight Speeds among Bird Species: Allometric and Phylogenetic Effects

Thomas Alerstam[1*], Mikael Rosén[1], Johan Bäckman[1], Per G. P. Ericson[2], Olof Hellgren[1]

1 Department of Animal Ecology, Lund University, Lund, Sweden, 2 Department of Vertebrate Zoology, Swedish Museum of Natural History, Stockholm, Sweden,

Flight speed is expected to increase with mass and wing loading among flying animals and aircraft for fundamental aerodynamic reasons. Assuming geometrical and dynamical similarity, cruising flight speed is predicted to vary as (body mass)$^{1/6}$ and (wing loading)$^{1/2}$ among bird species. To test these scaling rules and the general importance of mass and wing loading for bird flight speeds, we used tracking radar to measure flapping flight speeds of individuals or flocks of migrating birds visually identified to species as well as their altitude and winds at the altitudes where the birds were flying. Equivalent airspeeds (airspeeds corrected to sea level air density, U_e) of 138 species, ranging 0.01–10 kg in mass, were analysed in relation to biometry and phylogeny. Scaling exponents in relation to mass and wing loading were significantly smaller than predicted (about 0.12 and 0.32, respectively, with similar results for analyses based on species and independent phylogenetic contrasts). These low scaling exponents may be the result of evolutionary restrictions on bird flight-speed range, counteracting too slow flight speeds among species with low wing loading and too fast speeds among species with high wing loading. This compression of speed range is partly attained through geometric differences, with aspect ratio showing a positive relationship with body mass and wing loading, but additional factors are required to fully explain the small scaling exponent of U_e in relation to wing loading. Furthermore, mass and wing loading accounted for only a limited proportion of the variation in U_e. Phylogeny was a powerful factor, in combination with wing loading, to account for the variation in U_e. These results demonstrate that functional flight adaptations and constraints associated with different evolutionary lineages have an important influence on cruising flapping flight speed that goes beyond the general aerodynamic scaling effects of mass and wing loading.

Citation: Alerstam T, Rosén M, Bäckman J, Ericson PGP, Hellgren O (2007) Flight speeds among bird species: Allometric and phylogenetic effects. PLoS Biol 5(8): e197. doi:10.1371/journal.pbio.0050197

The Journal of Experimental Biology 200, 2355–2361 (1997)

JEB1058

2355

ACTUAL AND 'OPTIMUM' FLIGHT SPEEDS: FIELD DATA REASSESSED

C. J. PENNYCUICK*

School of Biological Sciences, University of Bristol, Woodland Road, Bristol BS8 1UG, UK

Accepted 25 June 1997

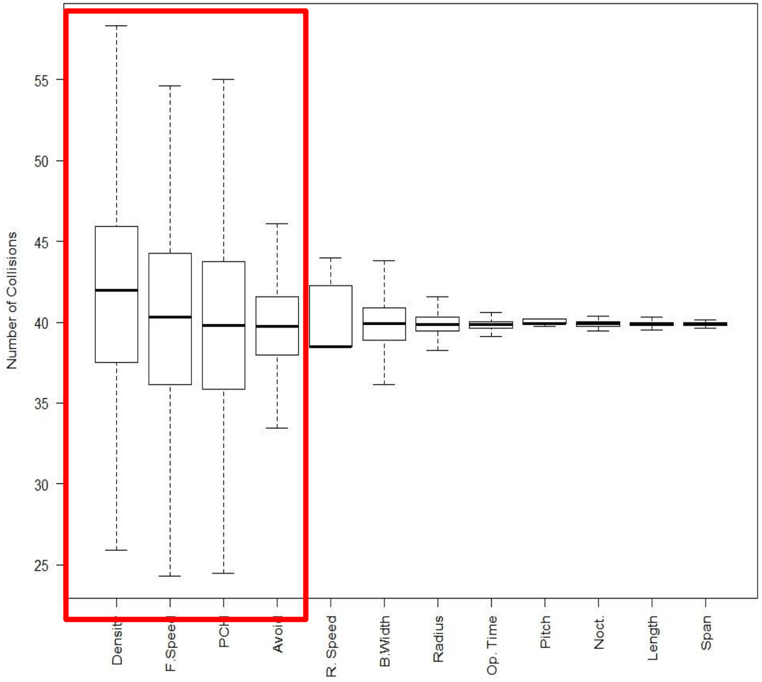
Summary

Previously published field observations of the air speeds of 36 species of birds, all observed by the same method (ornithodolite), were compared with estimates of the corresponding minimum power speeds, calculated with a default body drag coefficient of 0.1. This value, which was derived from recent wind tunnel studies, represents a downward revision from default values previously used and leads, in turn, to an upward revision of estimated minimum power speeds. The mean observed air speeds are now distributed around the minimum power speed, rather than in between the speeds for minimum power and maximum range, as they were before. Although the field data do not represent migration, examination of the marginal effects of small changes of speed, on power and lift:drag ratio, indicates that flying at the maximum range speed on migration may not represent an 'optimal' or even a practical strategy and that cruising speeds may be limited by the muscle power available or by aerobic capacity. Caution in constructing 'optimisation' theories is indicated.

Key words: bird, flight, speed, measured optimum.

Flight Speed

- Similar sensitivity to avoidance rate/bird density/PCH (Masden 2015)
- Low sample sizes, i.e. Kittiwake
  - 2 radar tracks, 660s
- Need for much better data & understanding of how representative it is



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Masden update of Band Model

Criticisms of Collision Risk Models

"Stop presenting single numbers as black and white and also provide context"

"…make modelling process more reproducible"

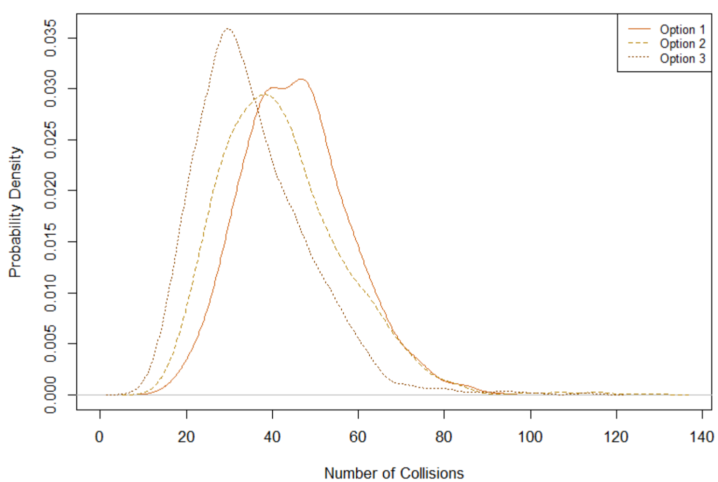
"Factor uncertainty into estimates"

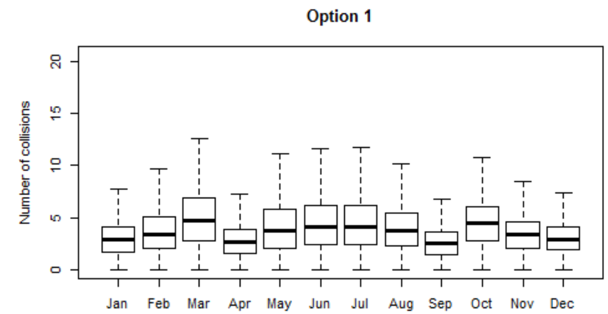
Masden update of Band Model

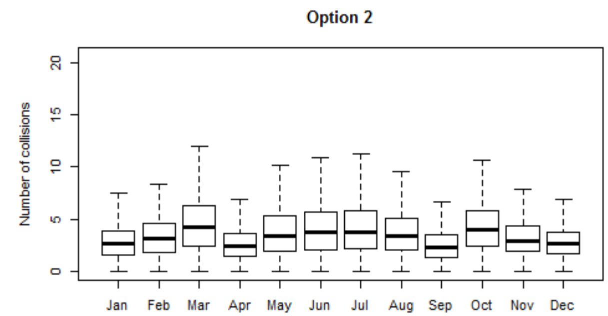
- Runs in R
- Monte Carlo Simulations
- Uses distributional data to estimate uncertainty around input parameters
- Also incorporates wind speed data to explicitly model relationship between wind & rotor speed/pitch

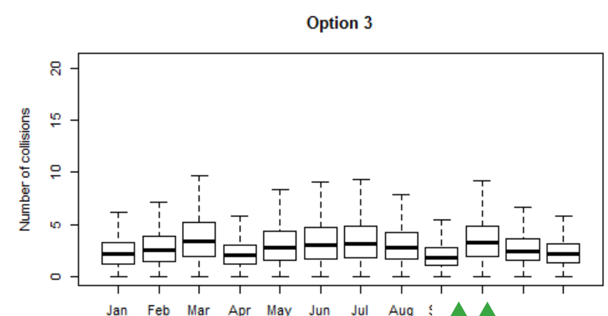
Masden update of Band Model

- Semi-automated
- Produces tables of input parameters & collision estimates
- Boxplot of monthly collision estimates
- Probability plot of collision numbers









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Results in the population context

Collision Rate Modelling

↓

number of collisions

=

number of dead birds

Level of mortality needed to bring about a change in the population:

- 1% of natural mortality
- Apply mortality to population models
- Potential Biological Removal (potential harvest)

1% of natural mortality

Originally defined for assessing hunting levels (EU ORNIS Committee).
In some countries widely applied for assessing effects of human activity.

Compares mortality to 1% of natural mortality threshold.

- >1% possible effect to be investigated further

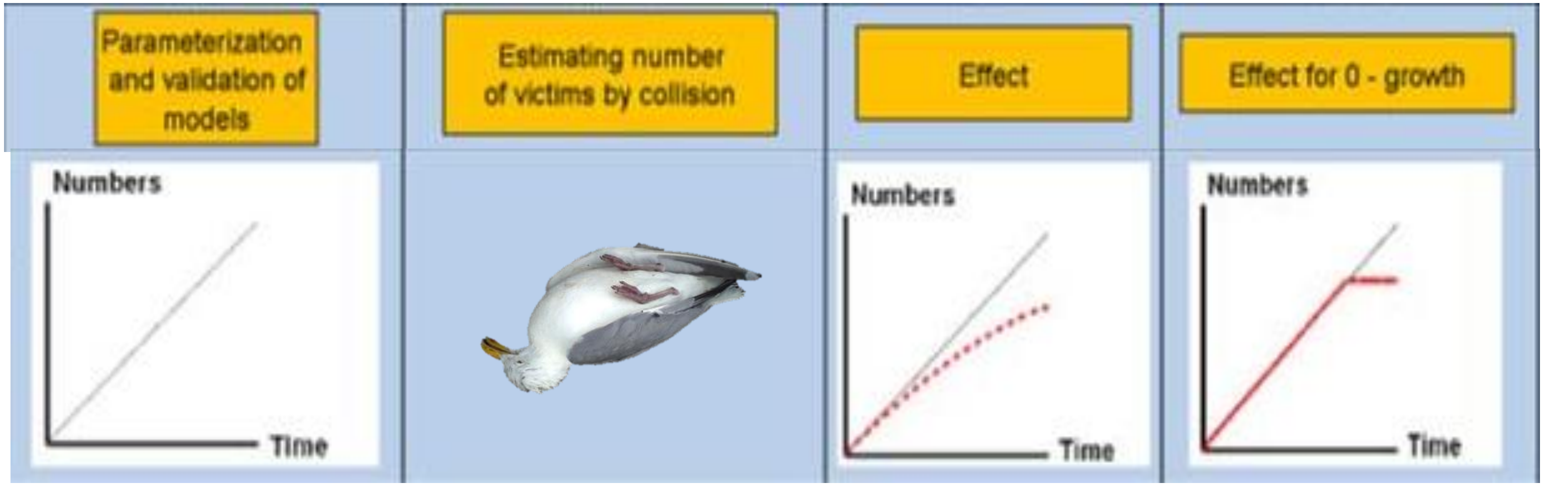
Colony in Wadden Sea 38,000 birds

adult survival 91.4% = 8.6% adult mortality

Annual mortality = 3,268 birds

1% annual mortality = 32.68

Population models



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Population models

- Data gathered on relevant populations;
  - Numbers
  - Life history parameters
    - Survival
    - Breeding success
    - Populations
    - Proportion of floaters
- Models based on matrix models

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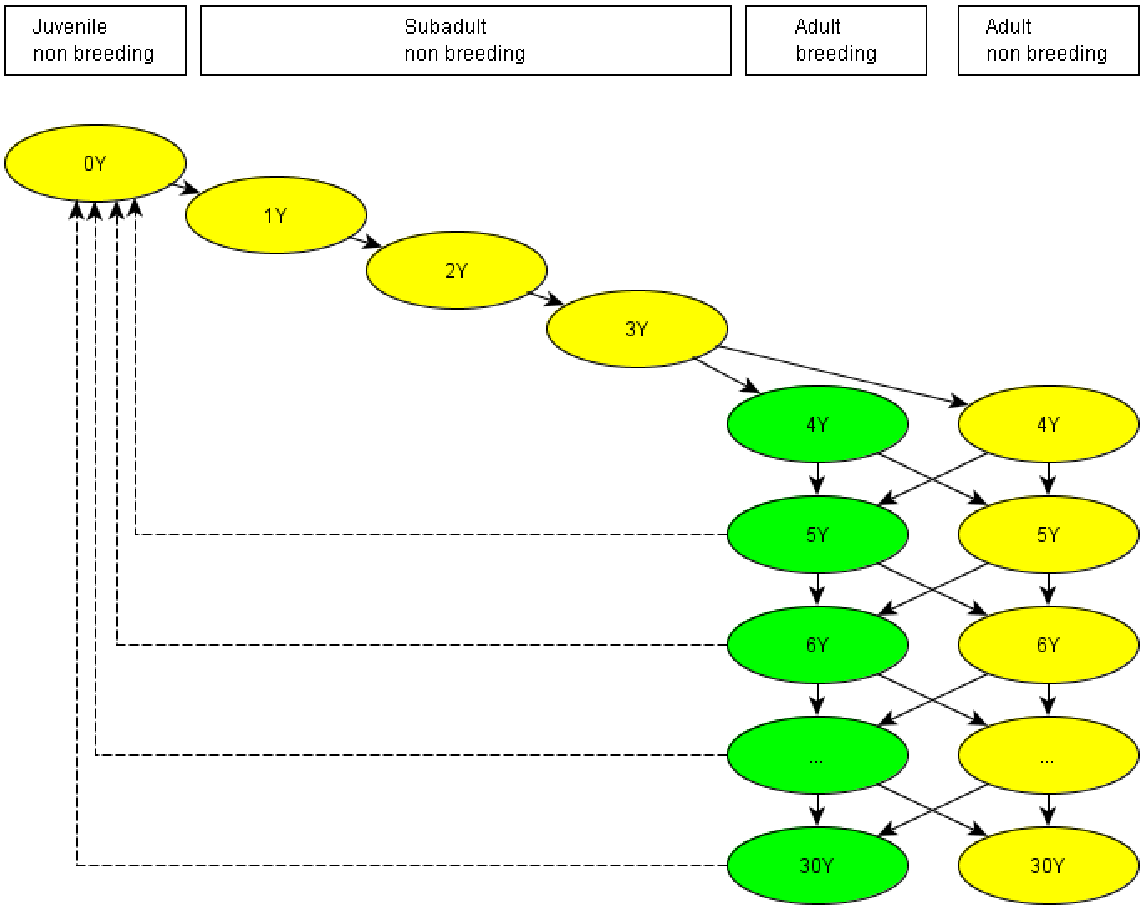
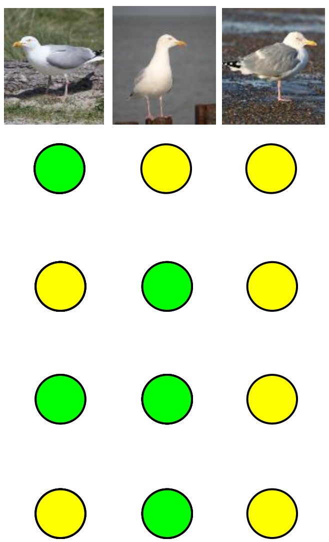
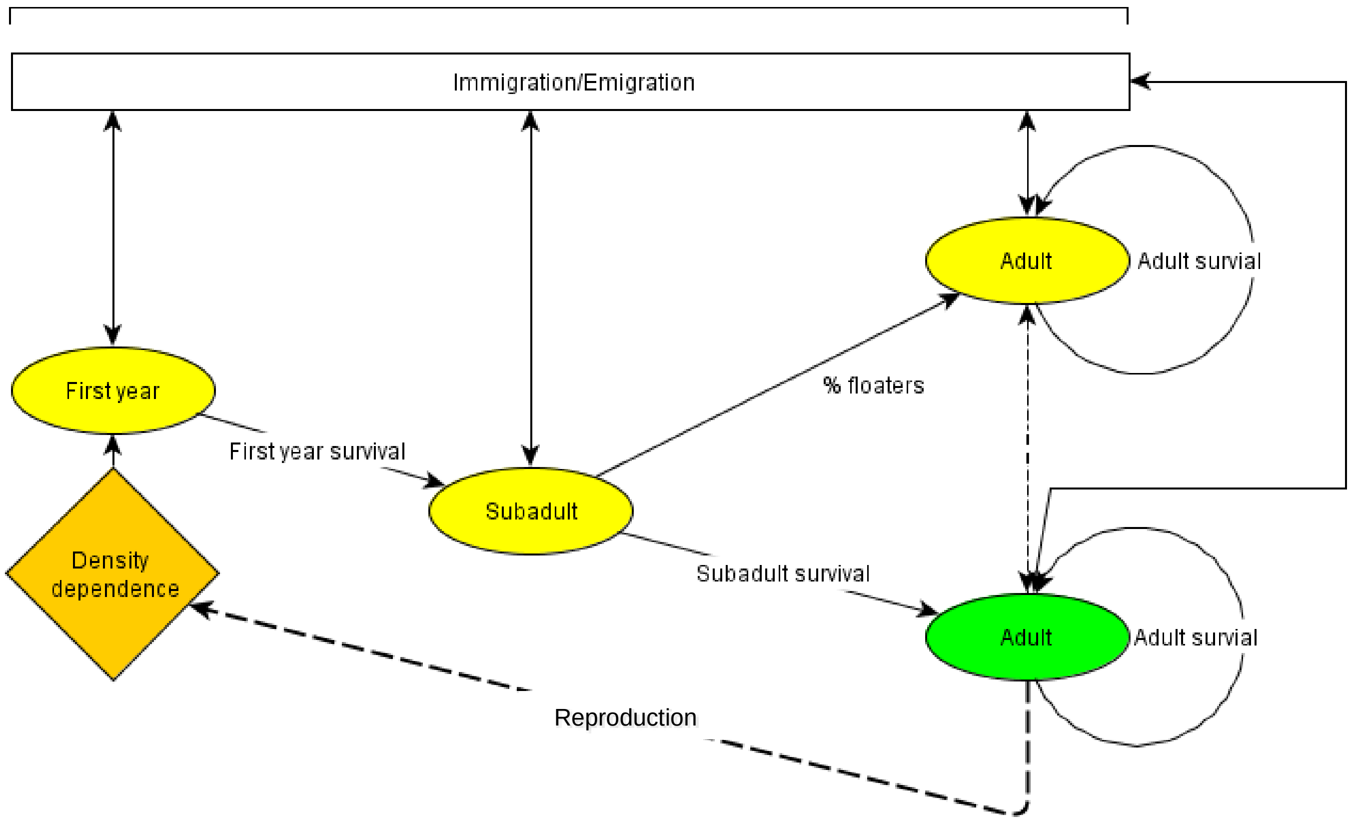
Population models





Poot, M.J.M., van Horssen, P.W., Collier, M.P., Lensink, R. & Dirksen, S. 2011. Effect studies Offshore Wind Egmond aan Zee: cumulative effects on seabirds A modelling approach to estimate effects on population levels in seabirds. Bureau Waardenburg 11-026, 247pp.

Population models



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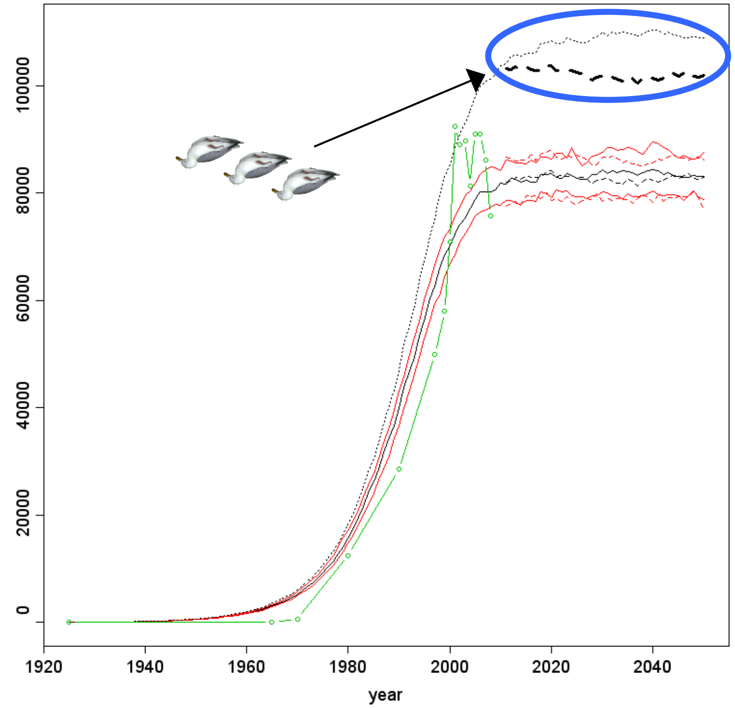
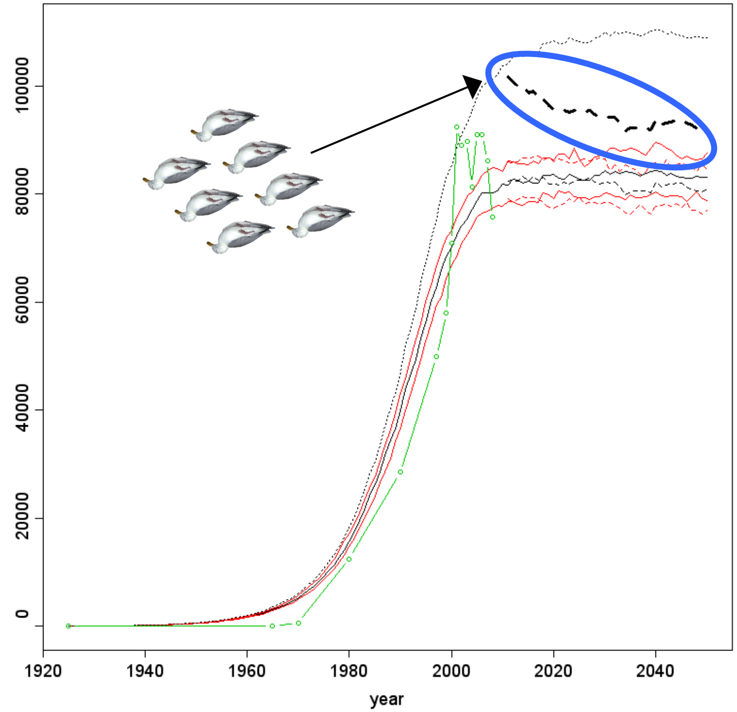
Population models

Lesser Black-backed Gull

Effect from CRM



Zero-growth/decline



850 collisions/yr

1,800 collisions/yr

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Potential Biological Removal (PBR)

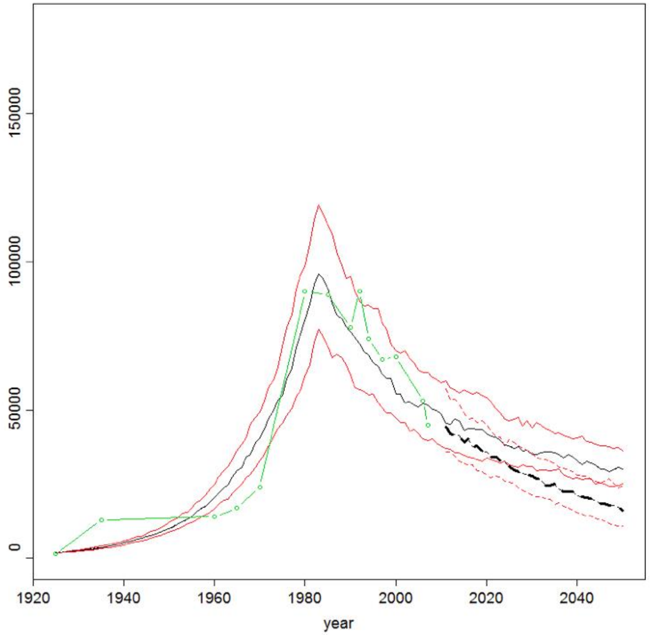
PBR approach (Dillingham & Fletcher 2008)

Level of sustainable mortality

Assesses recovery potential of population = ability to recover

Developed for small populations (cetaceans)

Requires less detailed population data.



Herring gull;

- CRM 11 wind farms = 585 collisions.
- declining population.
- PBR population can sustain 1,200 /yr.

Cautionary approach treated as *near threatened*

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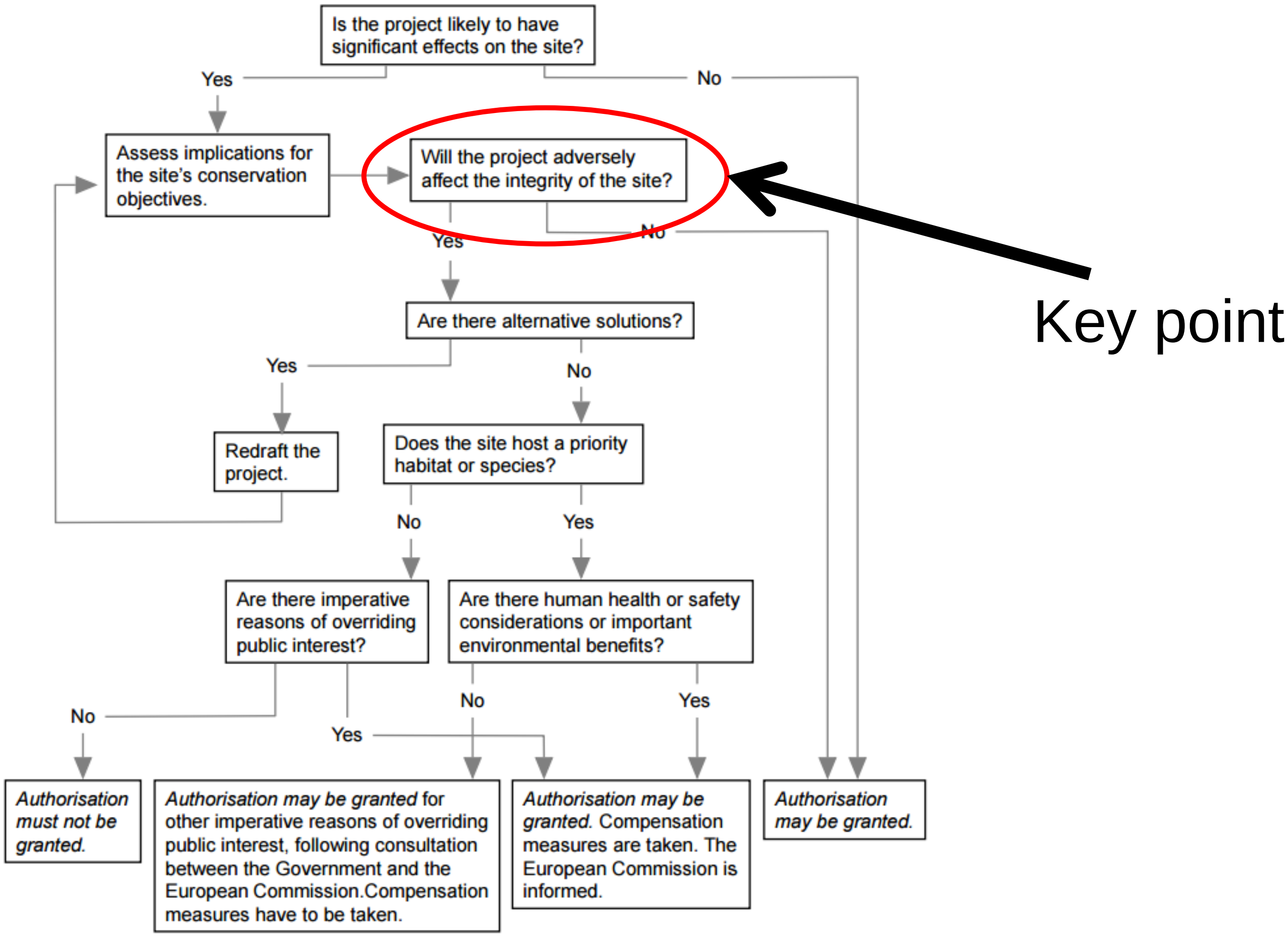
Legislative context



http://infrastructure.independent.gov.uk/wp-content/uploads/2011/04/Advice-note-10-HRA-web.pdf

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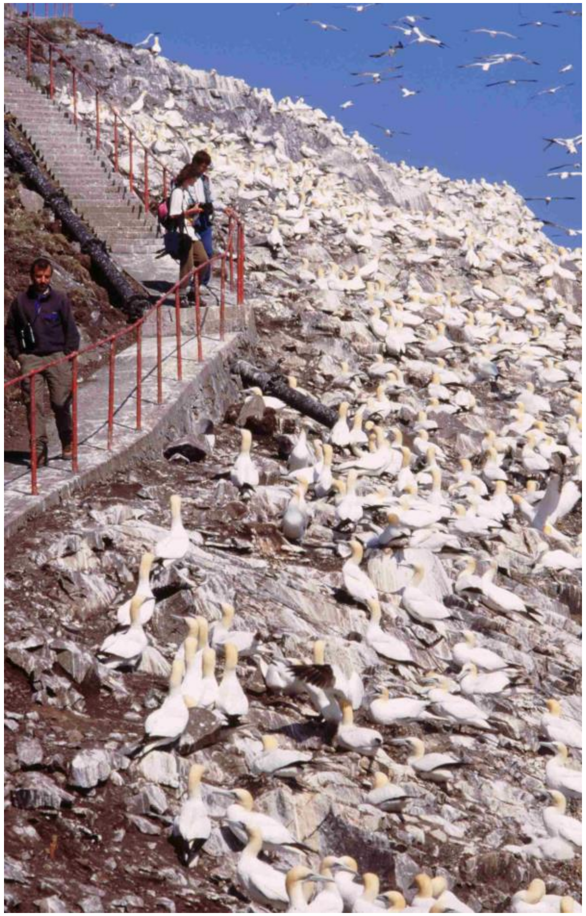
Will the project <u>adversely affect</u> the <u>integrity</u> of the site?

- Link to conservation objectives
- Population of qualifying features must be maintained/restored
- Must ensure that any impacts do not cause populations to decline



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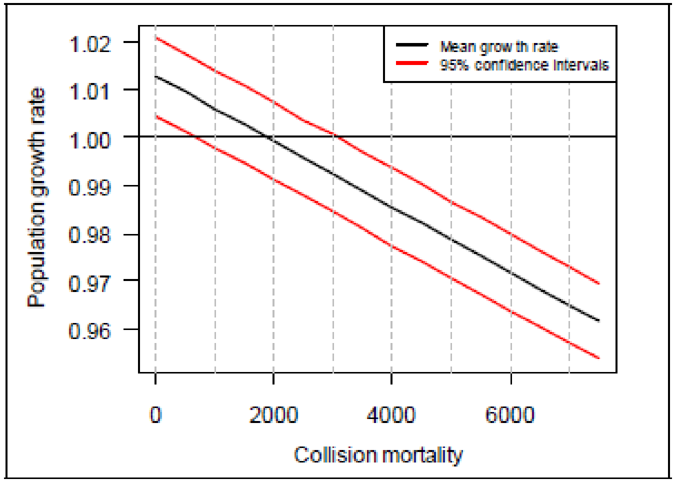
Assessing impacts

- Population Viability Analysis (PVA)
  - Can derive a range of metrics
- Potential Biological Removal (PBR)
- Acceptable Biological Removal (ABC)
- Suitability of metrics subject to debate
- Concerns relating to
  - Uncertainty in demographic parameters
  - Uncertainty in impacts
  - Relevance to conservation objectives



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Summary

Collisions considered the main effect of wind energy on birds.

Collision rate modelling can assess effects:

- pre-construction
- where victim searches are not feasible i.e. offshore

Field data required to inform models:

- Numbers of birds (fluxes)
- Flight heights
- Avoidance

Estimated number of collisions can be assessed in relation to:

- 1% criterion
- population models
- PBR

Compare in context of population and other pressures

More information

BTO
www.bto.org
aonghais.cook@bto.org
@_BTO / @AonghaisC

Bureau Waardenburg
www.buwa.nl/en
m.p.collier@buwa.nl
@buwanl / @markcolliernl

Band Model
http://www.bto.org/science/wetland-and-marine/soss/projects