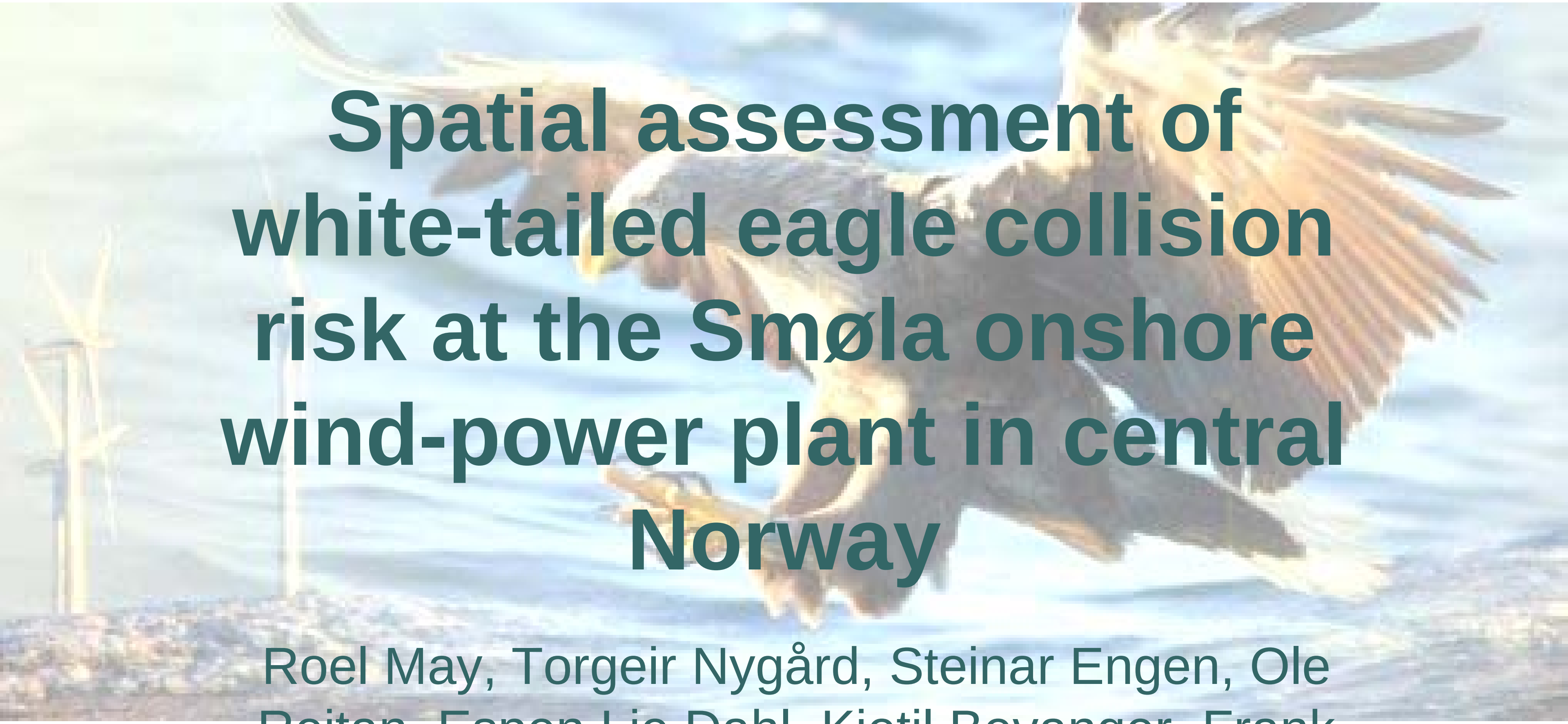

Spatial assessment of white-tailed eagle collision risk at the Smøla onshore wind-power plant in central Norway

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NINA
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Background

Centre for Environmental Design of Renewable Energy (CEDREN)

TOOLS – tools for hydropower production

HydroPEAK – hydropower balancing

EnviPEAK – environmental impacts of hydropeaking

EnviDORR – increased power and salmon production

GOVREP – governance for renewable electricity production

OPTIPOL – optimal design and routing of power lines

BirdWind – birds and wind turbines

- Document species-, site- and season-specific mortality
- Behaviour and response studies at the individual and population level (choosen model species)
- Development of a population model for white-tailed eagles
- Modelling of collision risks
- Terrain modelling – prediction of high-risk areas
- Development of technical tools (avian radar, camera)

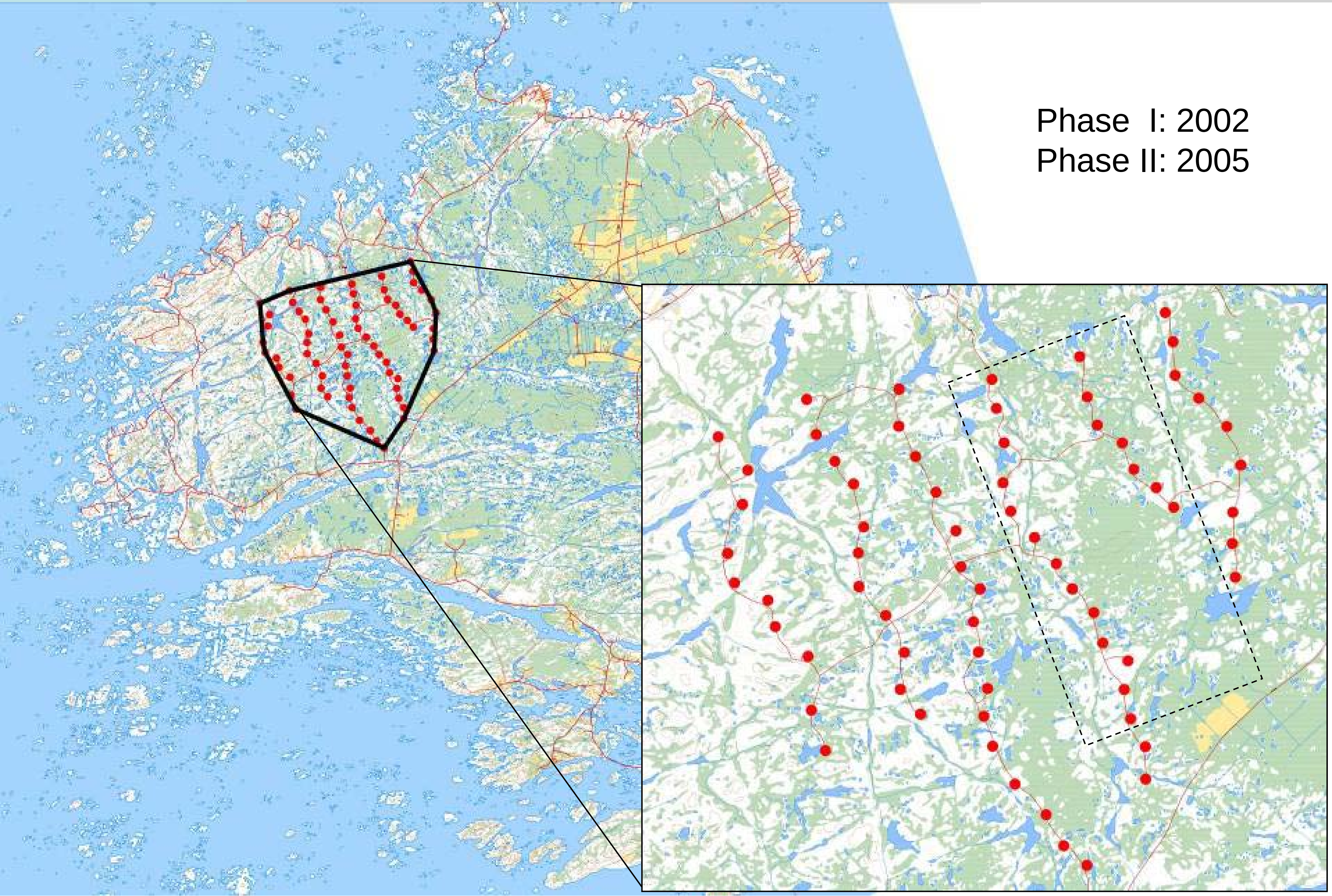
www.cedren.no

Background

- Smøla is an archipelago with one main island (274 km^2) and over 5000 islets and skerries (~2000 inhabitants)

Background

- Smøla is an archipelago with one main island (274 km^2) and over 5000 islets and skerries (~2000 inhabitants)
- The Smøla wind-power plant has been built in 2 phases in 2002 and 2005
- The wind-power plant has 68 wind turbines and is the largest in Norway
- ~60 white-tailed eagle territories on Smøla



Phase I: 2002
Phase II: 2005

Background

- 145 birds have been killed since autumn 2005 due to collisions with wind turbines at the Smøla wind-power plant
- Especially willow grouse (42) and white-tailed eagle (38) are susceptible to collisions
- Other species: common snipe, hooded crow, gulls, golden plover, greylag goose and ducks

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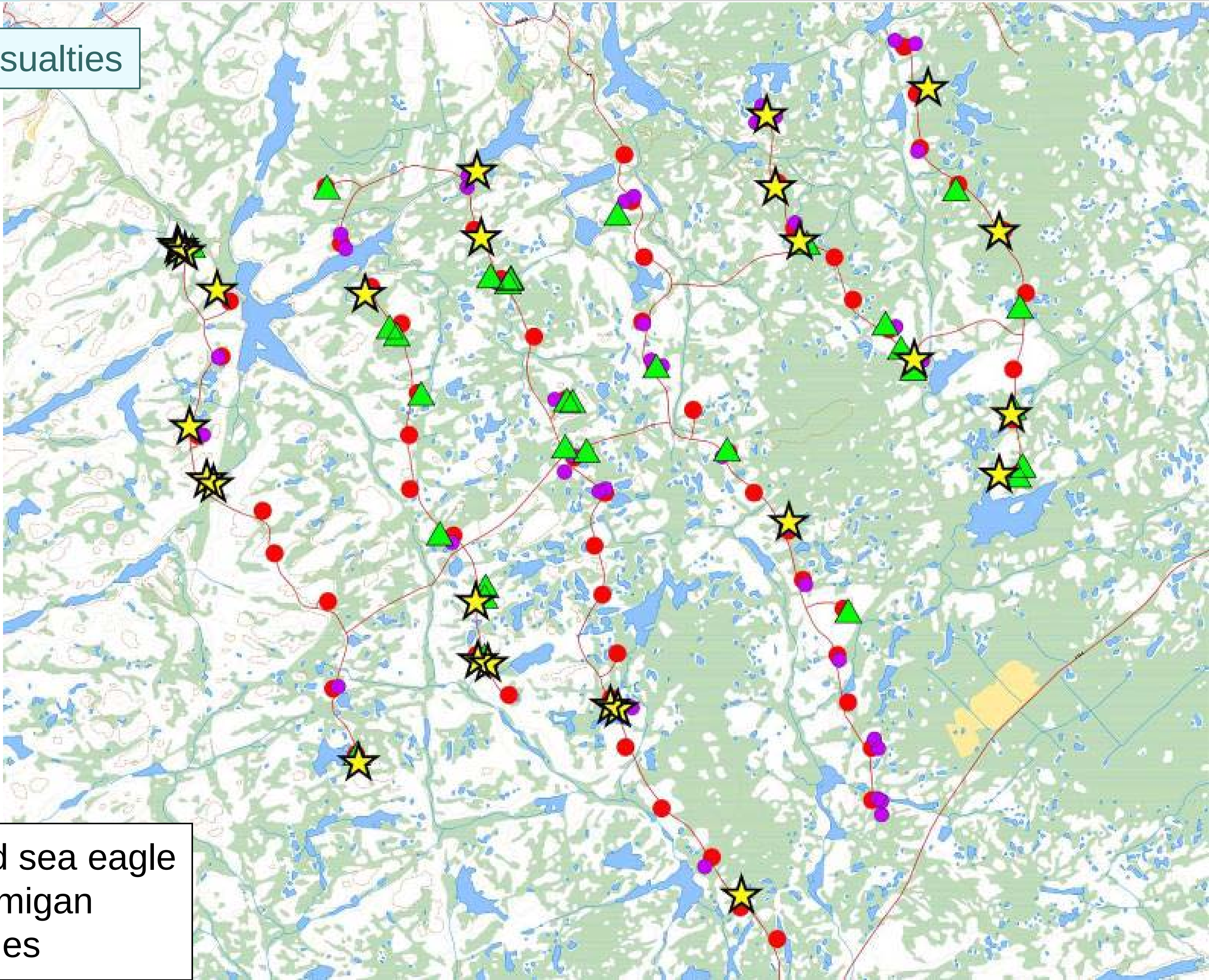
Recorded casualties



Collision risk modelling

- "Band-model", 2-stages:
  1. calculated likelihood of a bird being hit by the rotor blades as it passes through the rotor-swept zone (RSZ)
  2. the estimated number of birds flying through the RSZ in a given time unit

Collision risk modelling - critique

- Stage 1:
  - based on the technical specifications of the turbines and the morphology, wing aspect, average speed and flight behaviour (flapping or soaring) of the bird
  - straightforward, but does not incorporate stochasticity due to variation in wind speed and direction, RPMs, flight speed and directionality

Collision risk modelling - critique

- Stage 2:
  - based on field observations, vantage points
  - prone to many potential sources of error and variations, such as field regime, observer skills, time of year, species-specific differences, terrain, weather conditions, etc.

Aims of the Study

- We here propose a method which makes use of the data delivered by the birds themselves, through the use of GPS satellite telemetry

- Amount of time spent within the wind-power plant, and within the rotor-swept zones over time
- Spatial-temporal assessment of collision risks with wind turbines

- A Brownian bridge approach...

GPS Tracking of Individual Sea Eagles

50 fledglings radio-marked
backpack Argos/GPS transmitters

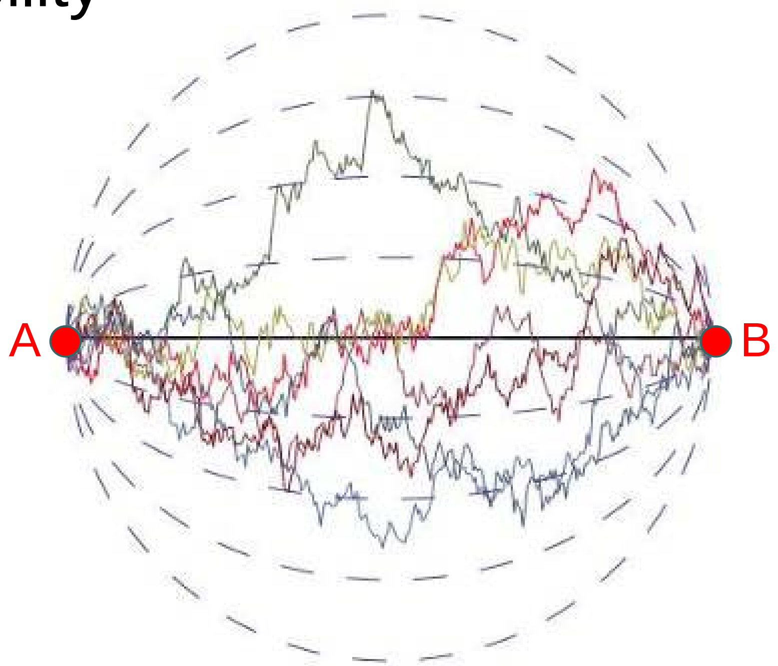
Microwave Telemetry Argos/GPS transmitter (70 g)

Brownian Bridges

"A Brownian bridge is a continuous stochastic process with a probability distribution that is the conditional distribution of a Wiener process given prescribed values at the beginning and end of the process, and where the steps are stationary and independent"

Brownian Bridges

Conditional random walk between successive pairs of locations, dependent on the time between locations, the distance between locations, and the Brownian motion variance that is related to the animal's mobility



Brownian Bridges

- Brownian bridges were calculated in intervals of 1 minute (Δt) for XYZ-coordinates independently
  - Only GPS positions <24 hours apart were included
  - Minimum of 20 GPS positions per subset

- The expected position b_t of an individual that moved randomly from $B_{T\text{-}1}$ to B_T (ΔB) at any point in time can be estimated using a normal distribution with variance which is proportional to the elapsed time between two consecutive GPS positions at $T\text{-}1$ and T (ΔT, for $T \geq 0$)

expected position
$b_t = B_{T-1} + \frac{\Delta B \cdot t}{\Delta T \cdot P_h}$

variance
$\sigma_t^2 = \frac{t \cdot (\Delta T - t)}{\Delta T \cdot P_h} \cdot \sigma_m^2 \cdot A_h$

Brownian Bridges

expected position
$$b_t = B_{T-1} + \frac{\Delta B \cdot t}{\Delta T \cdot P_h}$$

variance
$$\sigma_t^2 = \frac{t \cdot (\Delta T - t)}{\Delta T \cdot P_h} \cdot \sigma_m^2 \cdot A_h$$

Variance of the Brownian motion:	$\sigma_m^2 \sim \Delta B^2 / \Delta T$
Resting behaviour:	probability of activity (P_h) binary activity bout (A_h)
Daily activity pattern:	hourly smoothed variance

Simulations

- Collision risk rates were estimated by interpolating GPS trajectories using Brownian bridges
- Inclusion of telemetry error:
  - estimated from 35 dropped transmitters for XY-coordinates (~19 and ~17m, respectively)
  - estimated directly from the data for Z-coordinate (~19m)
- Risk rates were calculated for each individual separately; for each calendar year and month
- The Brownian bridge simulation was iterated 10 times

Simulations

- Z-coordinates were logit-transformed, bounded by 0 and 1,000 m agl
- Brownian bridge interpolation on Z-coordinates
- Derivation of activity bouts (A_h), with Z > 0 represented activity (=1)
- Brownian bridge interpolation on X- and Y-coordinates independently
- These simulations were stopped using the activity bouts

➢ *Activity bouts may also be derived directly from* $\mathrm{P_h}$ *when only 2D data is available (and multiplied by proportion within RSZ)*

Simulations

- “Risk rates” = the ratio of the number of simulated trajectories within the risk areas by the total number of simulated trajectories (minutes/day)

- Levels of assessment of risk rates – passing times:
  - The turbine areas (2D): surface area within a circular buffer of rotor blade length (38.0 and 41.2 m, for construction phase I and II respectively)
  - Because only locations within the RSZ are potentially dangerous, 3D risk rates within the turbine areas were estimated within an altitude band of 29-111 m
  - The wind-power plant area (WP): minimum convex polygon encompassing all turbine areas
  - Relative risk: 3D risk rate / Wind-power plant risk rate

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Results

We used analysis of variance to assess the explanatory effects of gender, distance between nest and wind power plant centroid, calendar year and month. Using generalized mixed models with a binomial distribution while controlling for within-individual effects (`lmer`).

females males

χ^2-values (sign.)	**WP rates**	**2D risk**	**3D risk**	**Relative risk**
Gender (*df*=*1*)	48.30*	1.39	0.48	3.09
Age (*df*=*3*)	3767.20*	29.53*	4.11	4.71
Month (*df*=*8*)	7018.36*	254.73*	25.20*	13.13

1st and 2nd year

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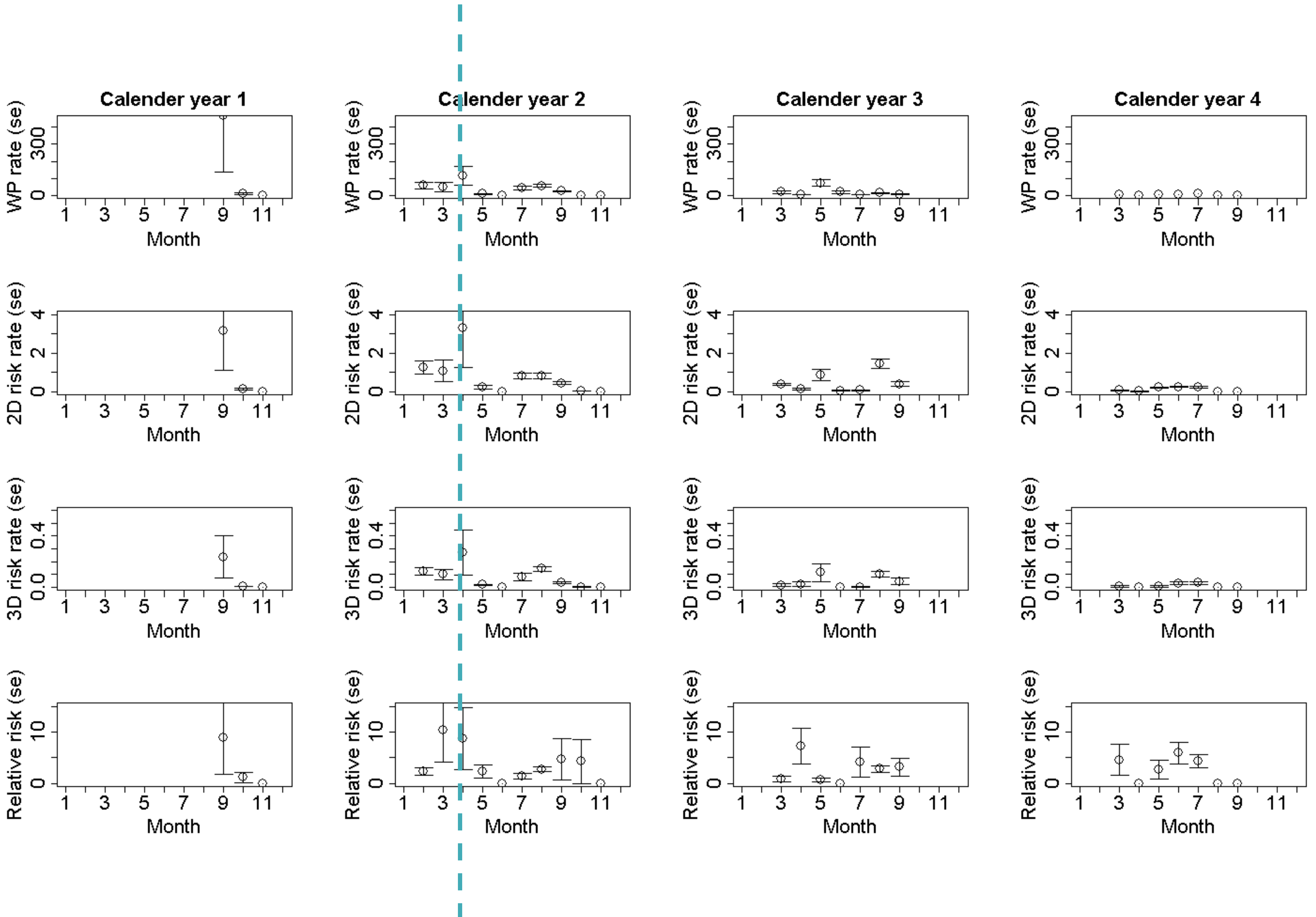
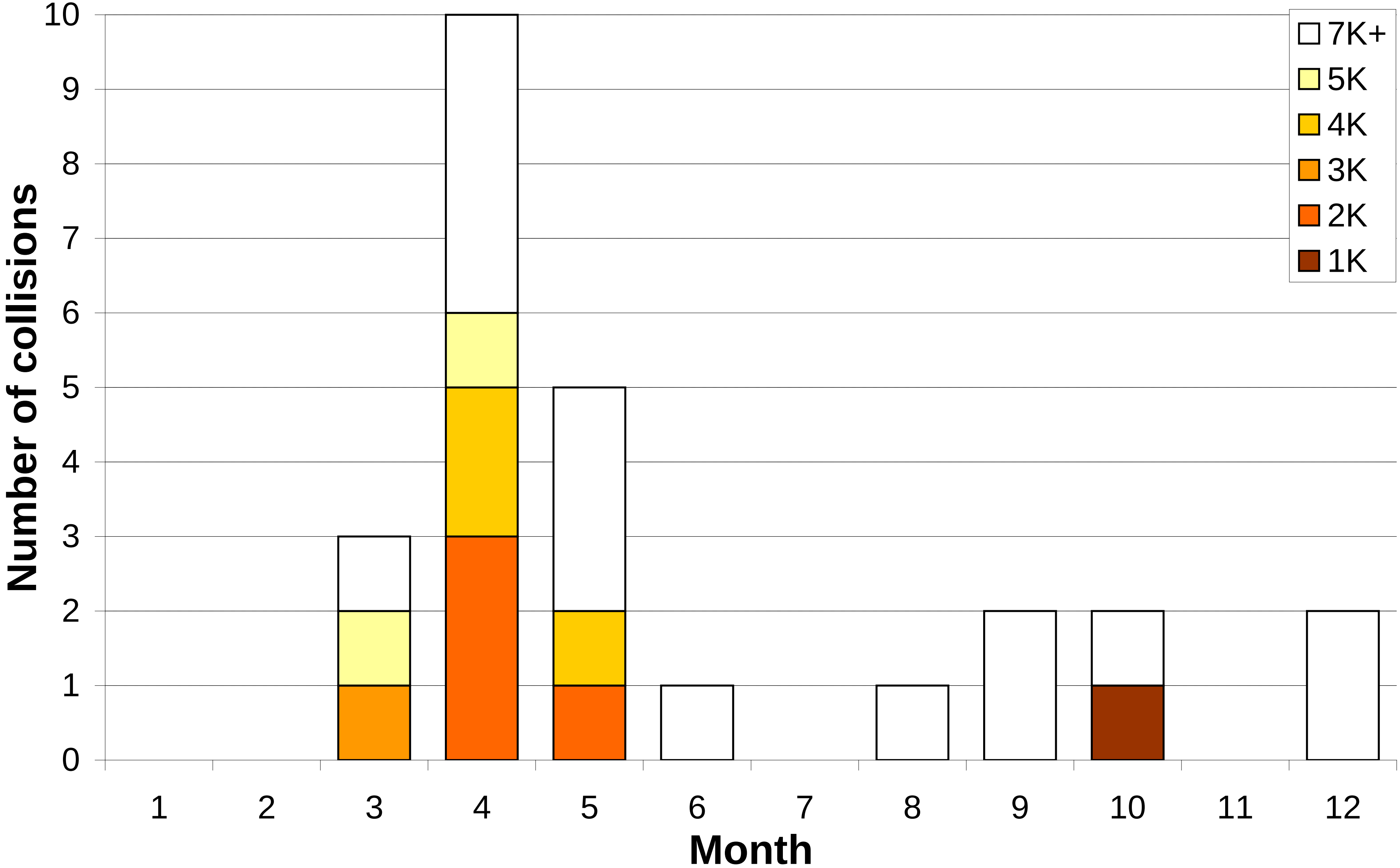
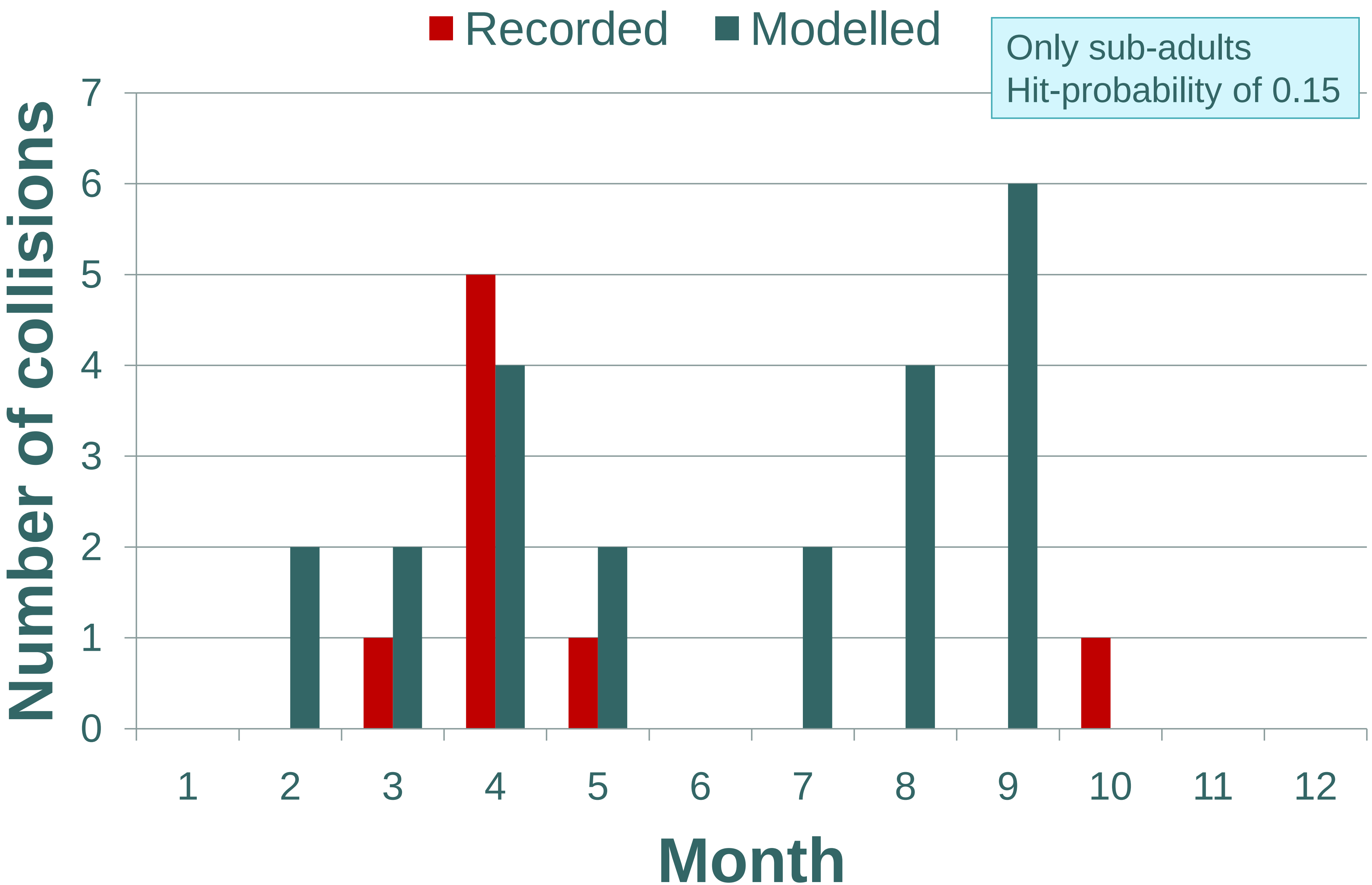

Calender year 1
Calender year 2
Calender year 3
Calender year 4
WP rate (se)
2D risk rate (se)
3D risk rate (se)
Relative risk (se)
Month

Recorded collision victims

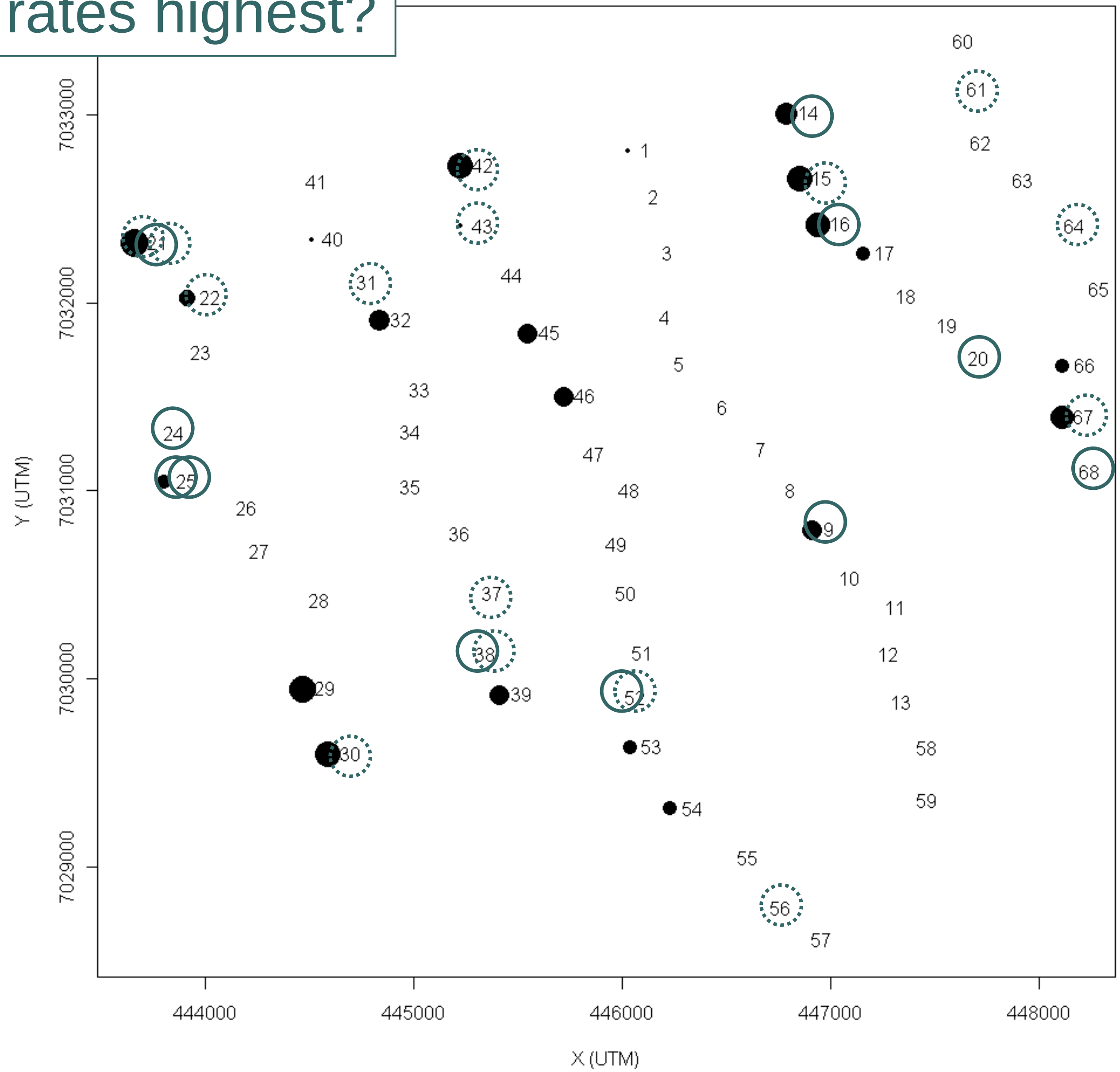




Recorded
Modelled
Only sub-adults
Hit-probability of 0.15
Number of collisions
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
10
11
12
Month

Where are the risk rates highest?

- subadults (1K-6K)
- adults (7K+)



Discussion

- Sub-adults more susceptible in their 1st and 2nd year of life
- Males display more risky behaviour within the wind-power plant
- Clear monthly patterns in collision risk rates
- Spring-time displaying behaviour
- Highest risk near edge-turbines

- Stochastic stage 1 of Band-model

- Inclusion of avoidance behaviour:
  - Avoidance of wind-power plant (cf. ‘forest’) ~ “displacement”
  - Avoidance of wind turbines (cf. ‘tree’)
  - Avoidance of moving rotor blades (cf. ‘branch’)

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Conference on
Wind energy and
Wildlife impacts

www.cww2011.nina.no

FIRST ANNOUNCEMENT

May 2-5 2011, Trondheim, Norway

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Thank you for your attention!