

Evaluating the Effectiveness of Flight Risk Models in Predicting Collision Risks for the Endangered Black Harrier (*Circus maurus*), an Endemic Breeding Raptor

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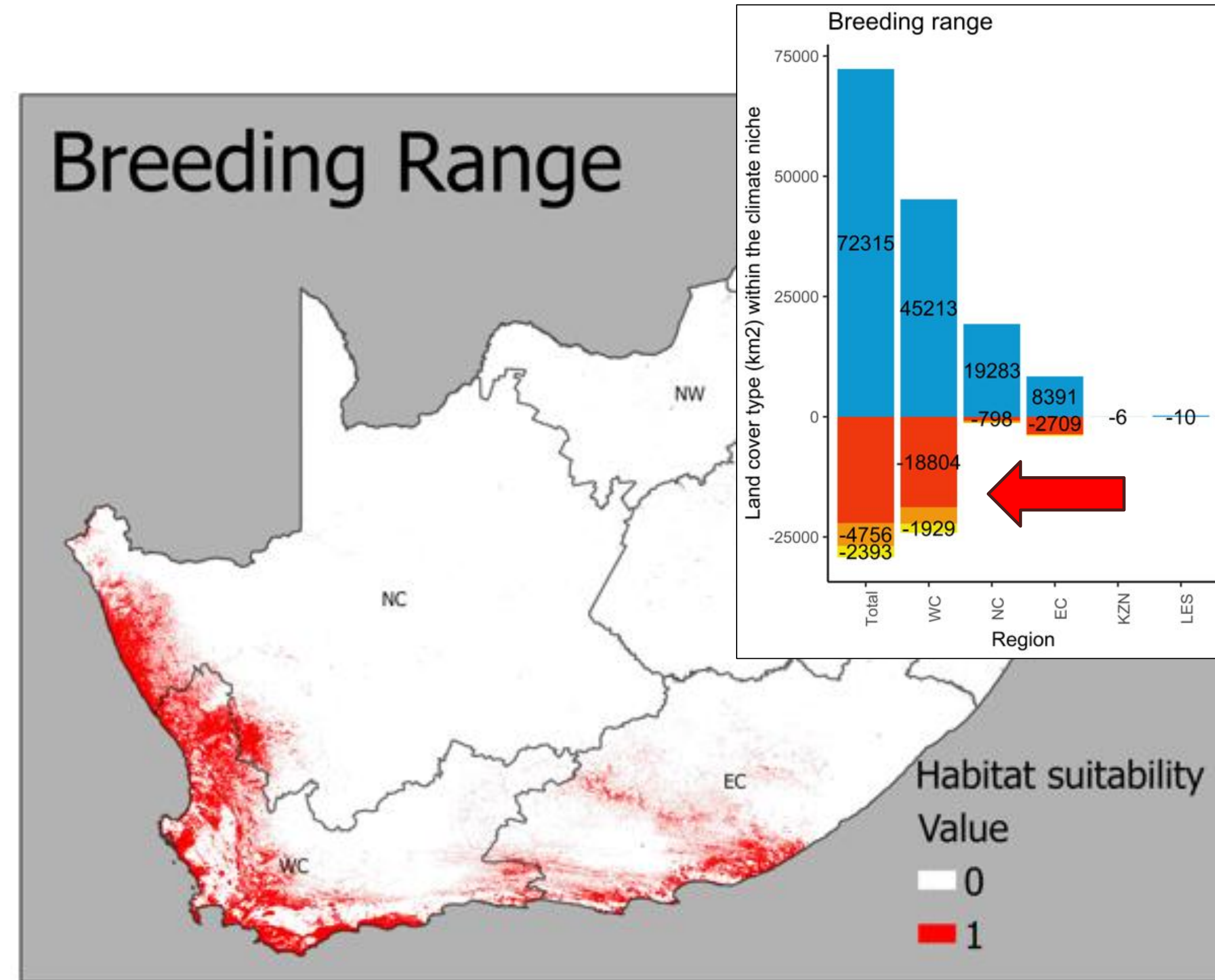
Co-organisers:



The Conservation Challenge

Black Harrier - A Species on the Brink:

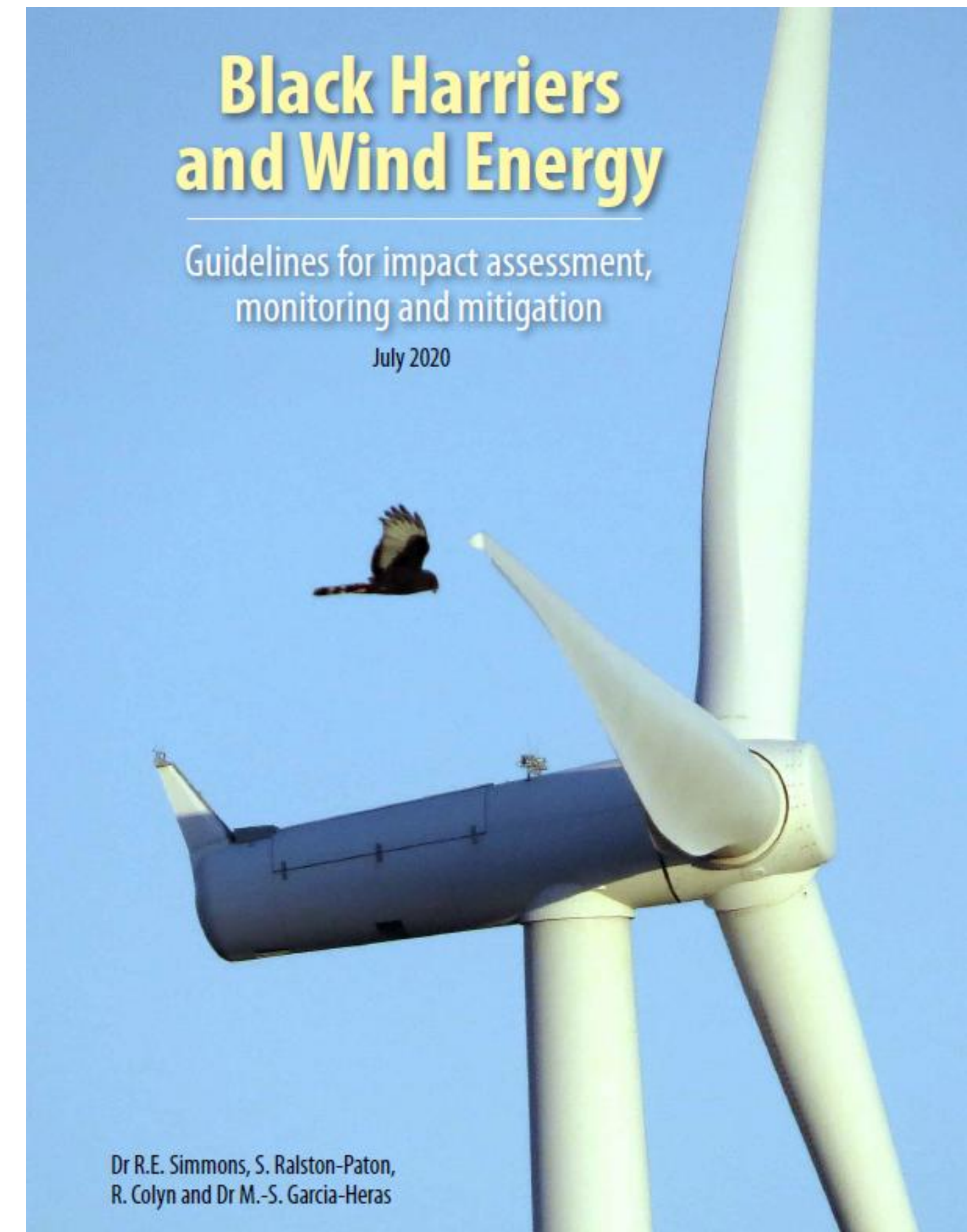
- **Endemic African raptor** – Endangered
- One of worlds rarest harriers (99% in South Africa).
- **Current population:** ~ 1,300 individuals
- 2.3% annual decline .
- **Critical vulnerability:**
 - Population could collapse in <100 years with 3-5 additional adult mortalities / year¹.
 - ~30% breeding habitat lost since 1980².
- **New threat:** Wind farms in core breeding range.



The Wind Energy Dilemma

Balancing Conservation and Renewable Energy:

- **Wind energy expansion:** Key for a carbon neutral future.
- **Collision risk:** ~10 Black Harrier fatalities recorded at wind facilities to date.
- **Projected impact:** Current and planned wind farms could exceed critical mortality thresholds for the species.
- **Management gap:** Current risk assessments and mitigation strategies are not reducing fatality rates.

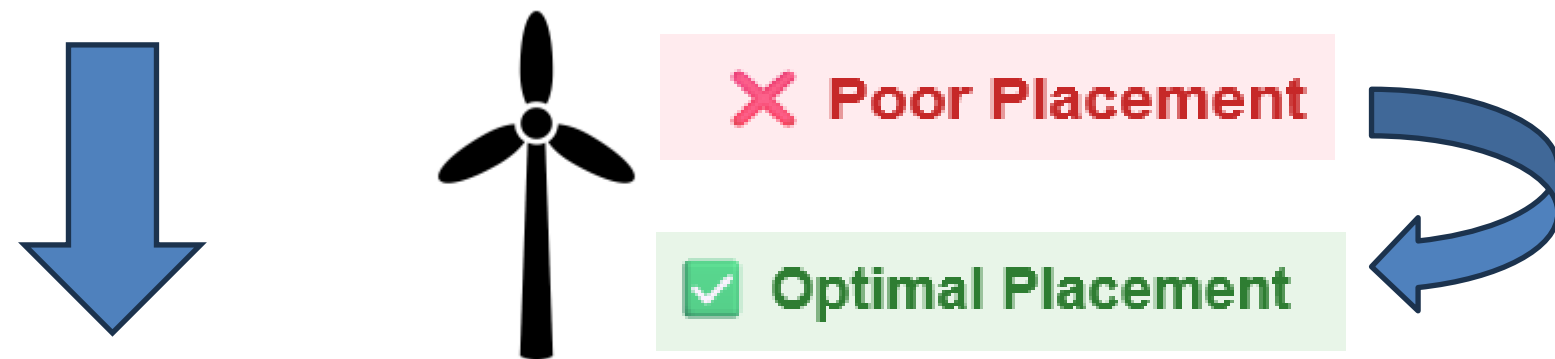


Research Objectives

Developing Predictive Flight Risk Models

A. Spatial Risk Models (Pre-construction risk assessment):

- Assess the spatial variables influence flight risk.
- Identify high-risk areas - nests and roosts.



- Delineate turbine avoidance areas.
- Optimize turbine placement.

B. Temporal Risk Models (Operational risk mitigation):

- Predict high-risk periods based on weather conditions and season.



- Enable proactive curtailment strategies.
- Tailor Shutdown on Demand (SDoD) schedules to best address the highest risk periods.

Study Approach

Data Integration and Model Development

Dataset:

- 18 tagged Black Harriers.
- ~250,000 GPS tracking points at high temporal resolution.
- Vantage point observer-recorded flight lines
- Post-construction collision mortality records (2 operational wind farms).
- Post-construction shutdown on demand data (observations of Black Harriers).

Data Processing:

Quality Control: Spatial/temporal cleaning to remove erroneous/low accuracy fixes.

Behavioral and nest/settlement area classification:

- Cluster analysis using dbSCAN, geosphere, nestR packages.
- Distinguish settlement areas (nests, roosts) vs. transitory flight behavior.
- Assess revisitation rates, minimum consecutive days visited, % fixes within cluster, etc.

Study Approach

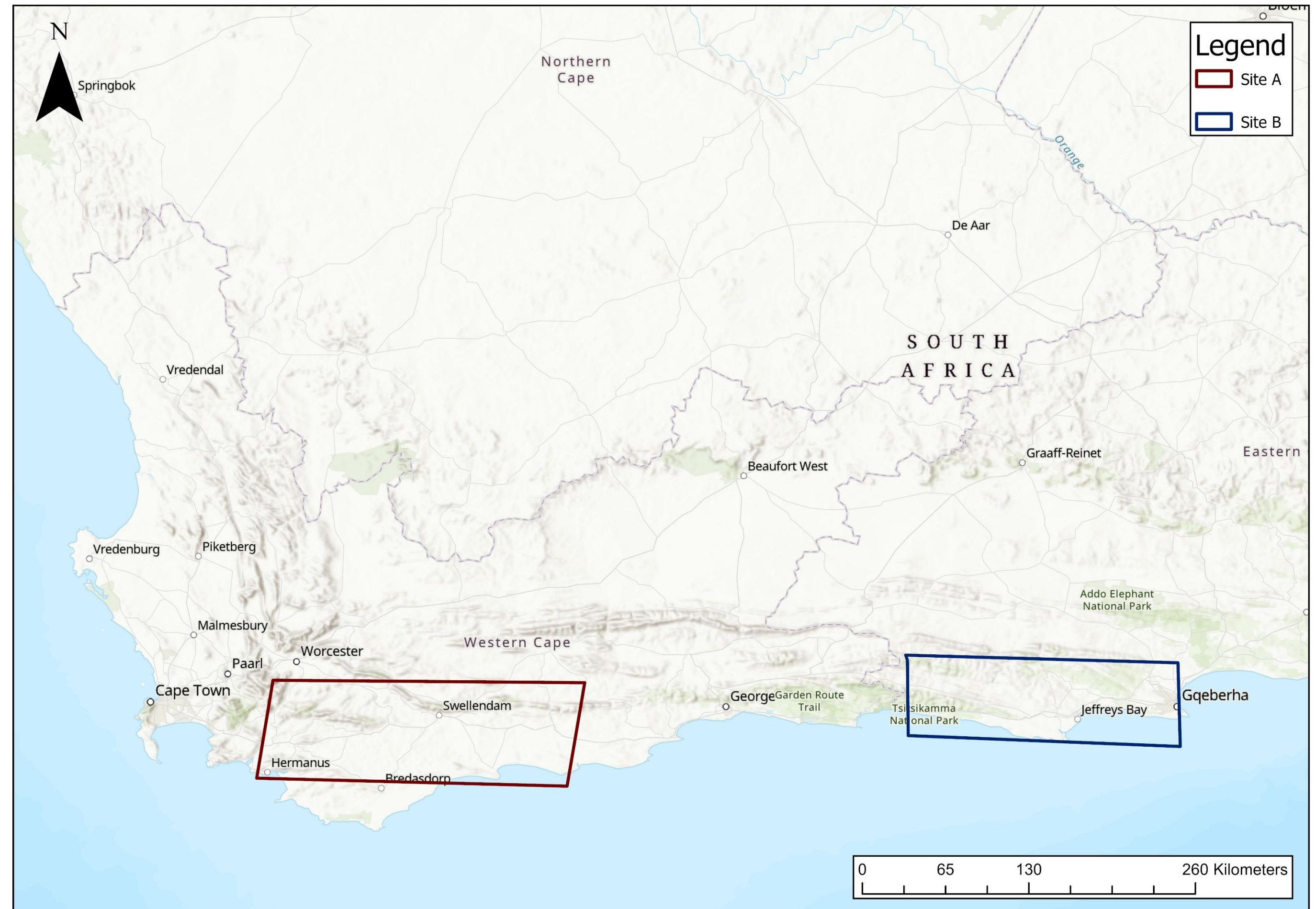
Study Sites:

Site A:

- East Coast Renosterveld bioregion
- Highly altered landscape.
- High seasonal densities of breeding and/or roosting birds.

Site B:

- Eastern Fynbos-Renosterveld Bioregion.
- More intact vegetation.
- High seasonal densities of breeding and/or roosting birds.



Study Approach



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Spatial Model Development:

Tracking Data Preparation:

- Risk flights: Filtered to rotor-swept area (25–300m AGL).
- Individual bird variation: Modelled with random intercepts.

Environmental Predictors:

1. Nest/roost proximity
2. Breeding habitat
3. Topographic features
4. Orographic and thermal uplift
5. Vegetation productivity

Modeling Approaches:

- Neural Networks
 - Deep learning with feature selection.
- Cross-validation
 - 5-fold validation grouped by bird.

Model Selection:

Feature selection found 6 important predictors.

Performance Metrics:

ROC-AUC, precision-recall, confusion matrices, partial dependence plots.

Results

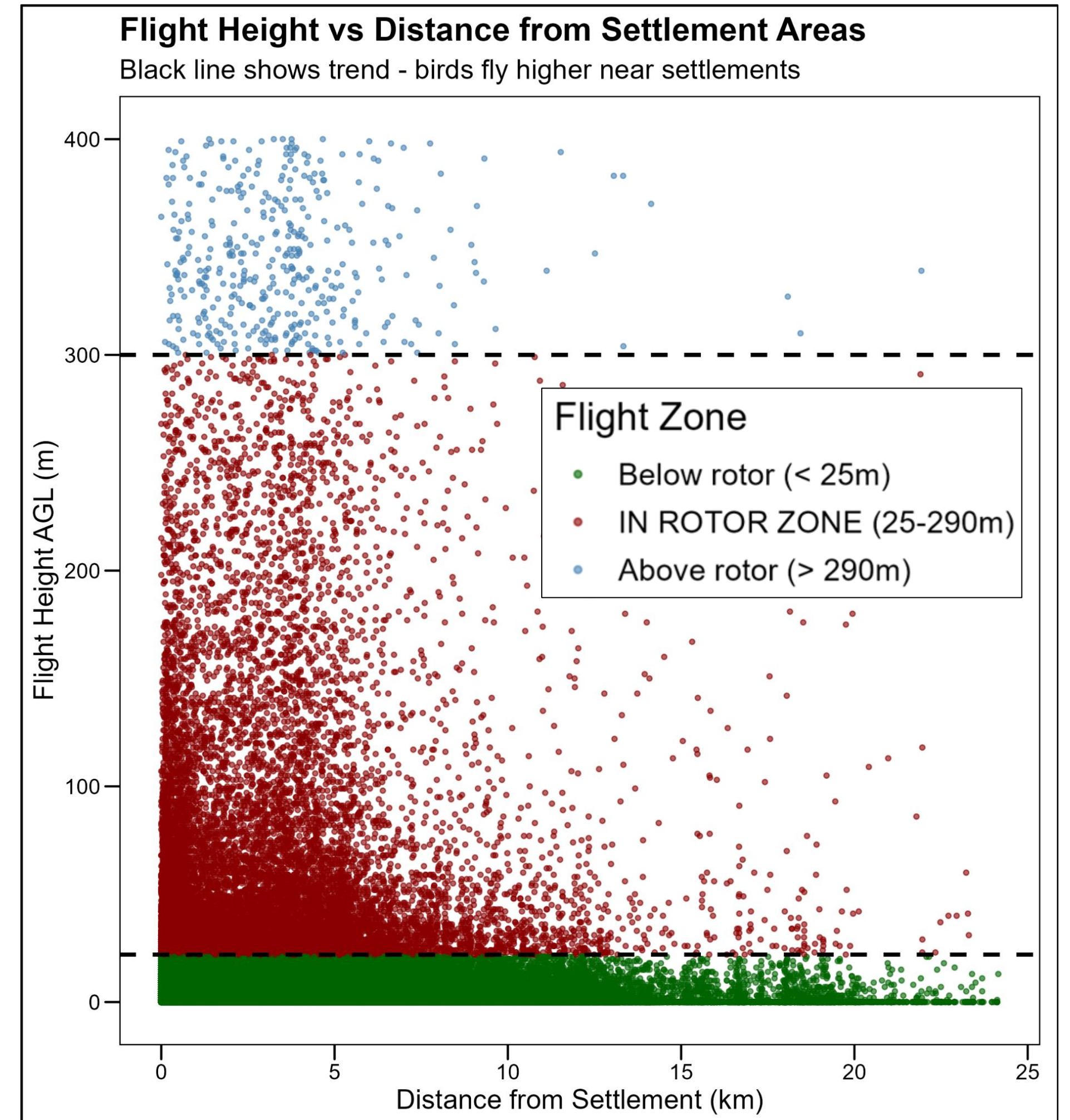
A. Spatial flight risk modelling

Proximity-Risk Relationship:

Highest rotor zone density within 0-5km of settlement areas (nests/roosts).

Decline in risky flights beyond 5km from settlements.

Sparse rotor zone activity beyond 10km from settlements.



A. Spatial flight risk modelling

Critical Distance Zones:

Peak-risk at 1-3km: Up to 20%

rotor zone exposure (August peak).

High-risk at 0-1km: 13% maximum

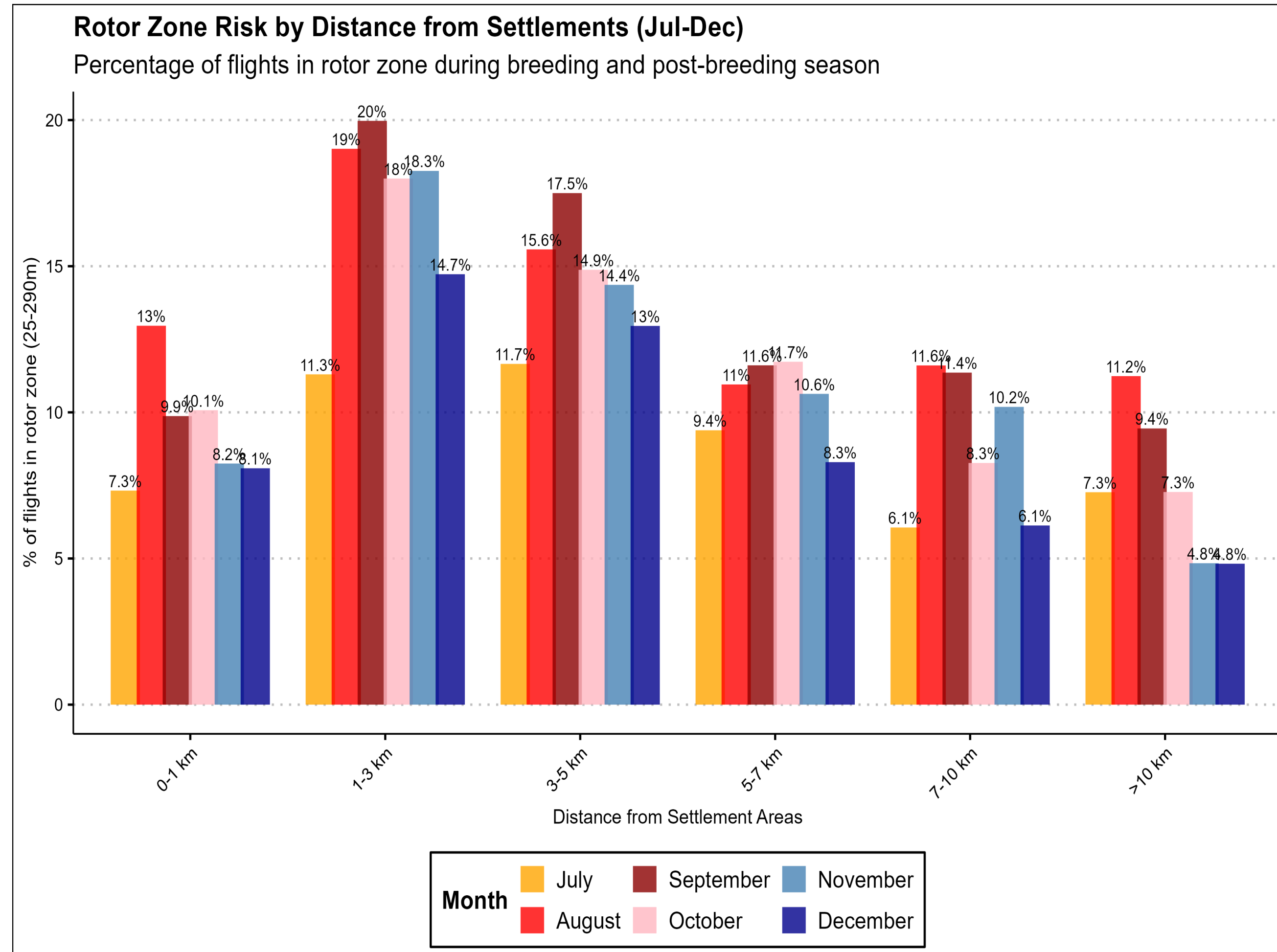
exposure during peak breeding.

Moderate-risk 3-5km: 10-17.5%

exposure during breeding months.

Low-risk beyond 7km: Consistently

<12% exposure across all months.



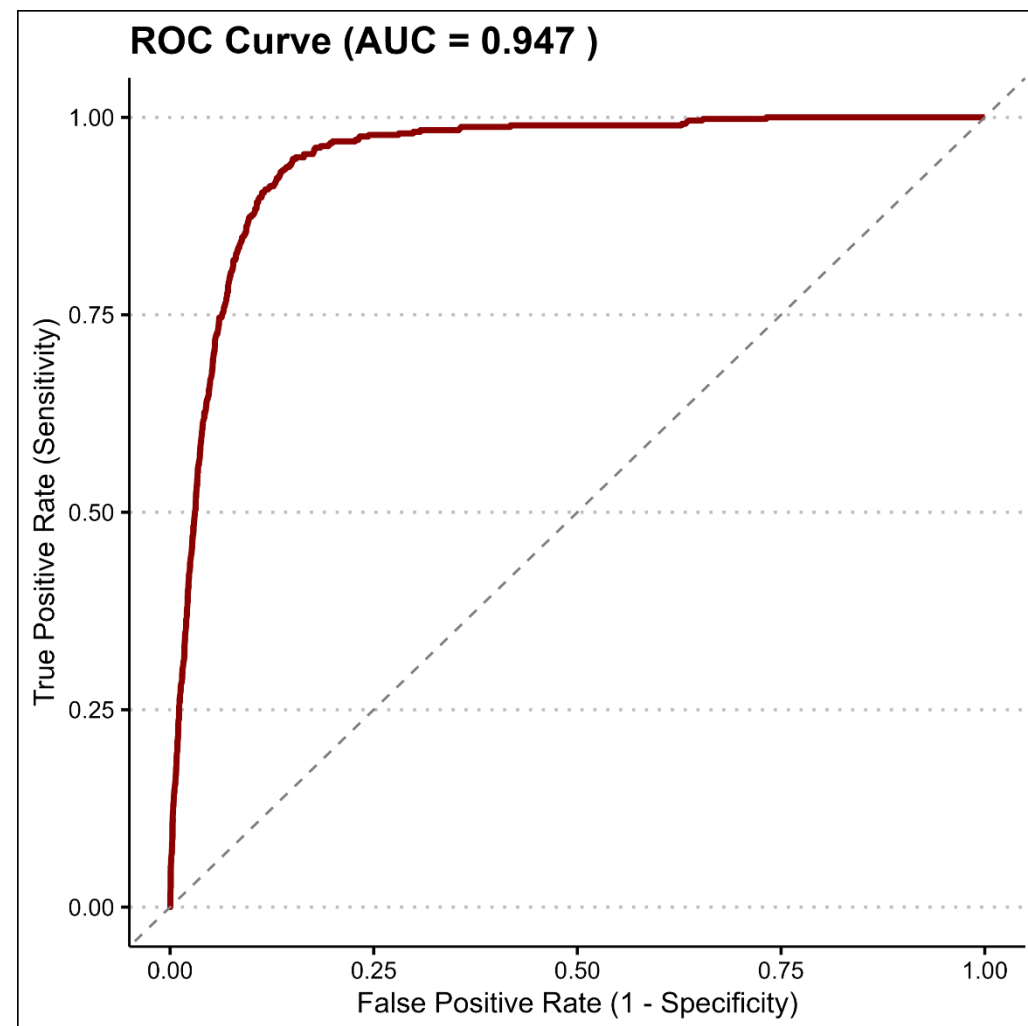
Results

A. Spatial flight risk modelling

Precision = 0.92

Recall = 0.91

F1 = 0.92



Key Predictive Variables:

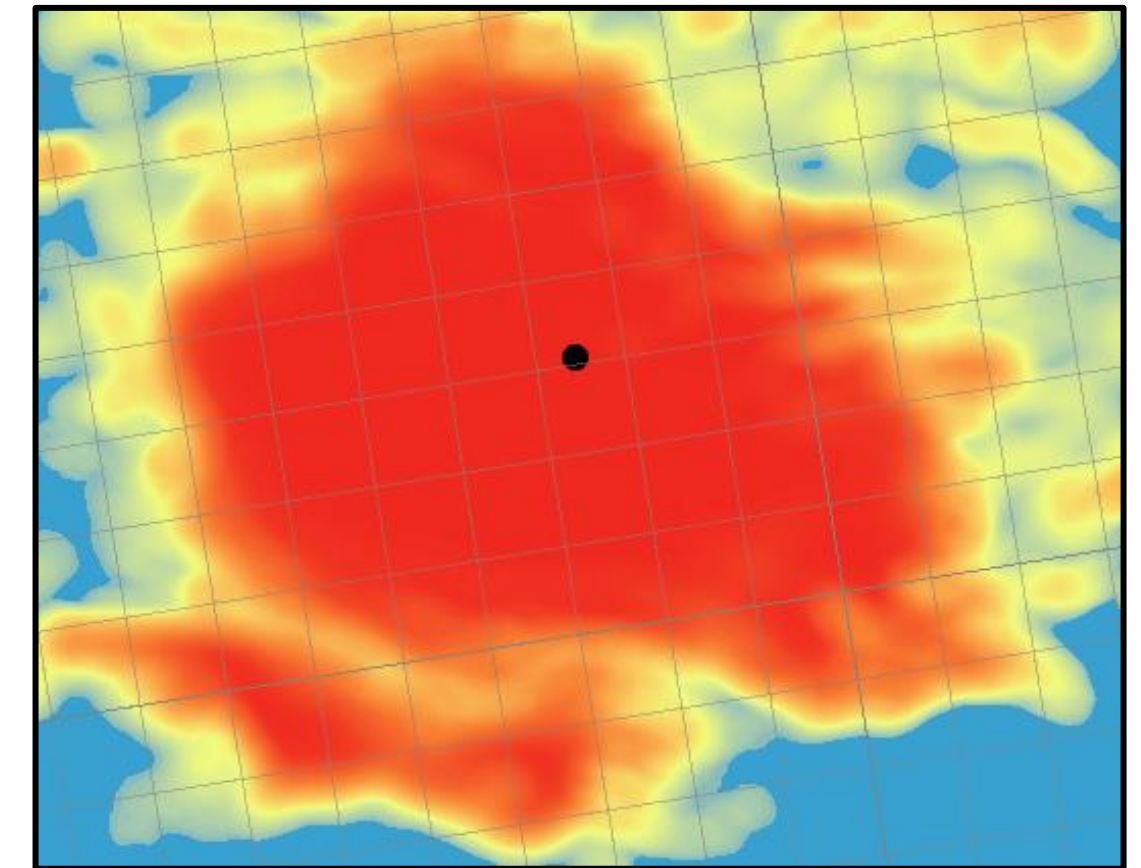
- Distance from/to nest/settlement area (-).
- Orographic uplift (+).
- Thermal yield/uplift (+).
- Habitat quantity (+).

Spatial Risk implications:

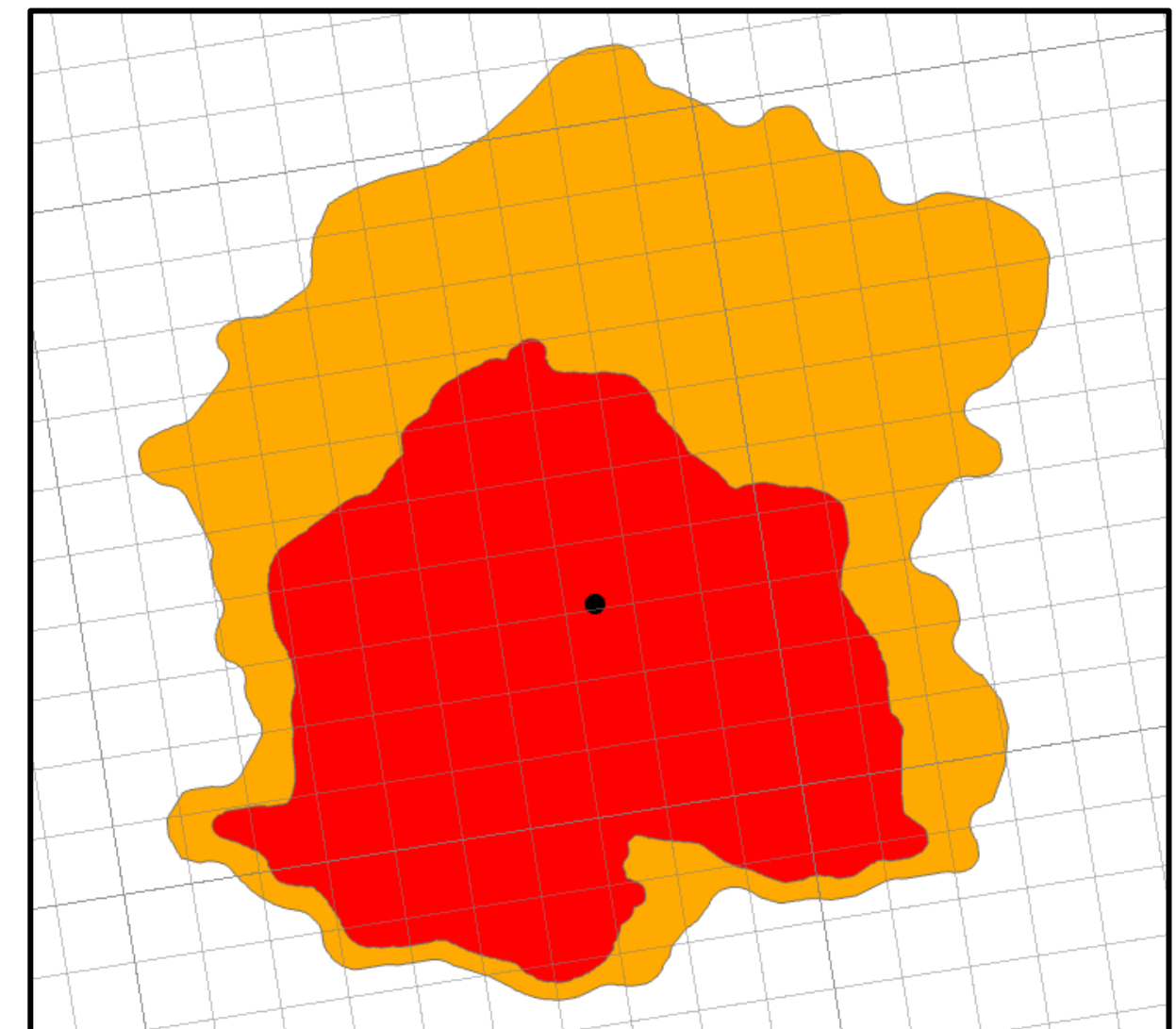
Very High risk = 50km² (within 4km of settlement areas).

Moderate-high risk = 100km² (within 5.5km of settlement areas).

Raw FRM



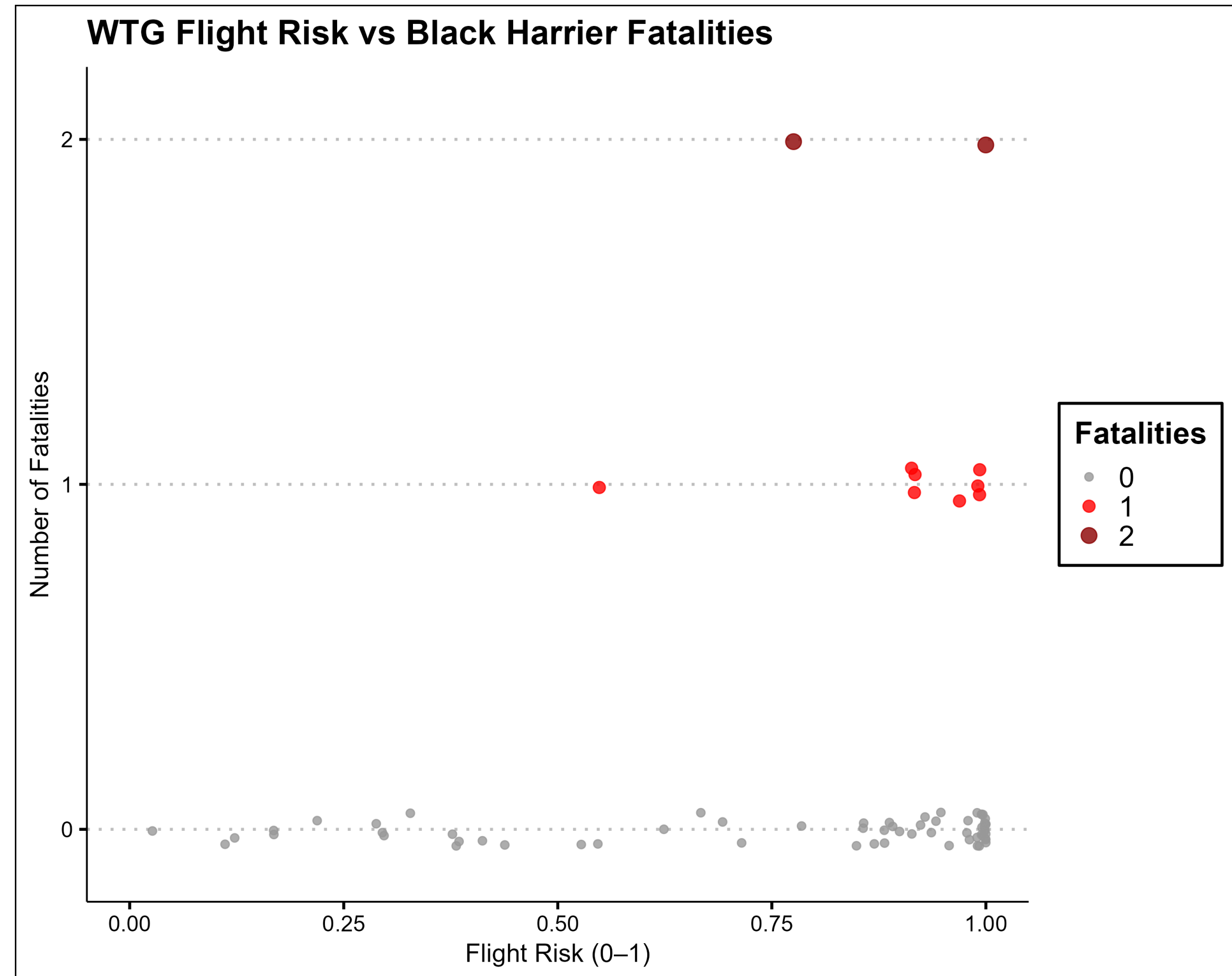
Processed FRM



A. Spatial flight risk modelling: test/validation

Fatality distribution:

- 9 of the 73 turbines recorded at least one fatality.
- A simple threshold of $FRM \geq 0.75$ classified **51 WTGs as “high risk”**.
- Those 51 high-risk WTGs accounted for 11 of the 12 fatalities (**$\approx 92\%$**).



B. Temporal flight risk modelling

Seasonal Risk Patterns:

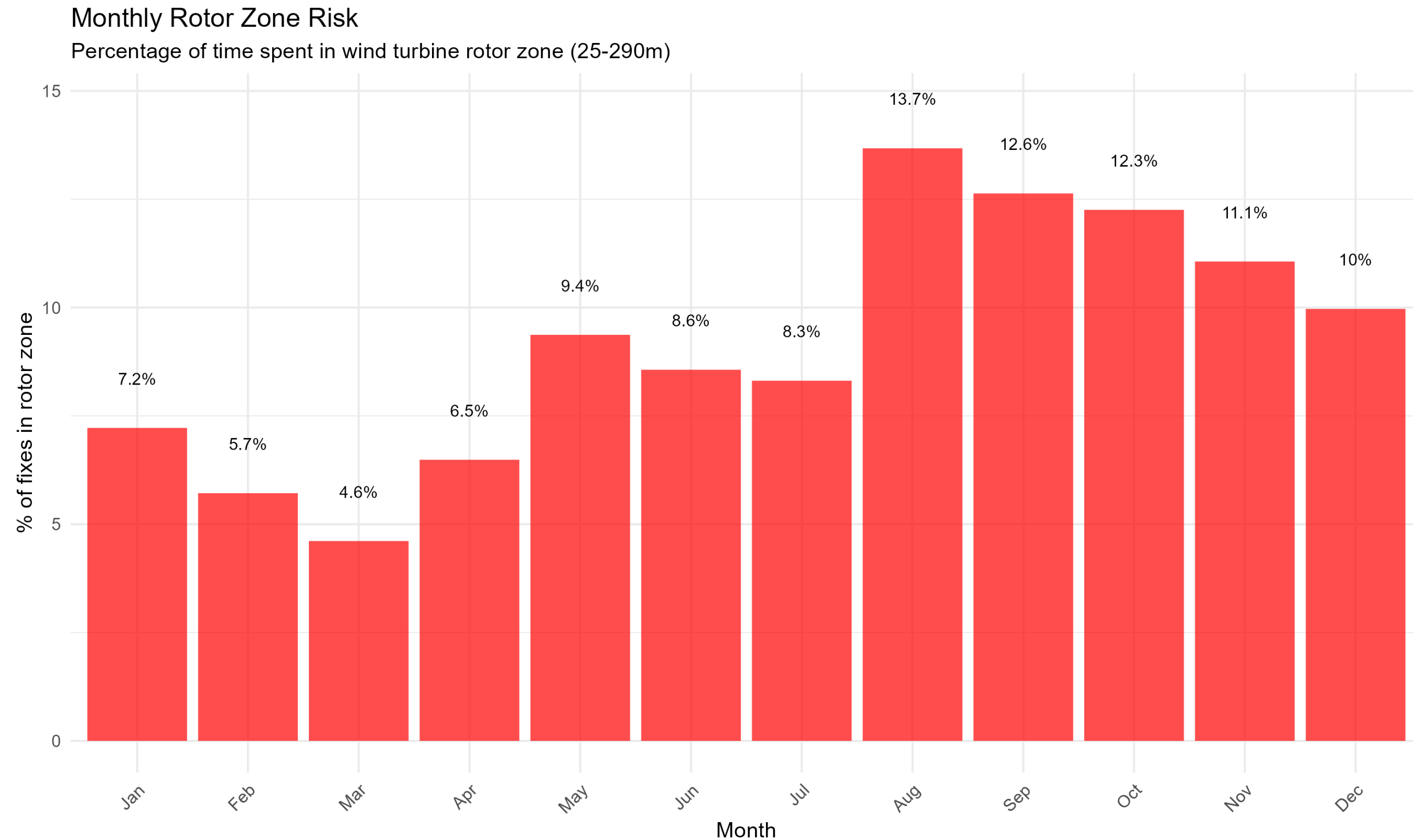
Peak risk period:

August-October (12.3-13.7% rotor zone exposure).

~**3x variation** between highest (August) and lowest (March) risk months.

Breeding Season Correlation:

Higher rotor zone exposure coincides with breeding season (Aug-Dec).



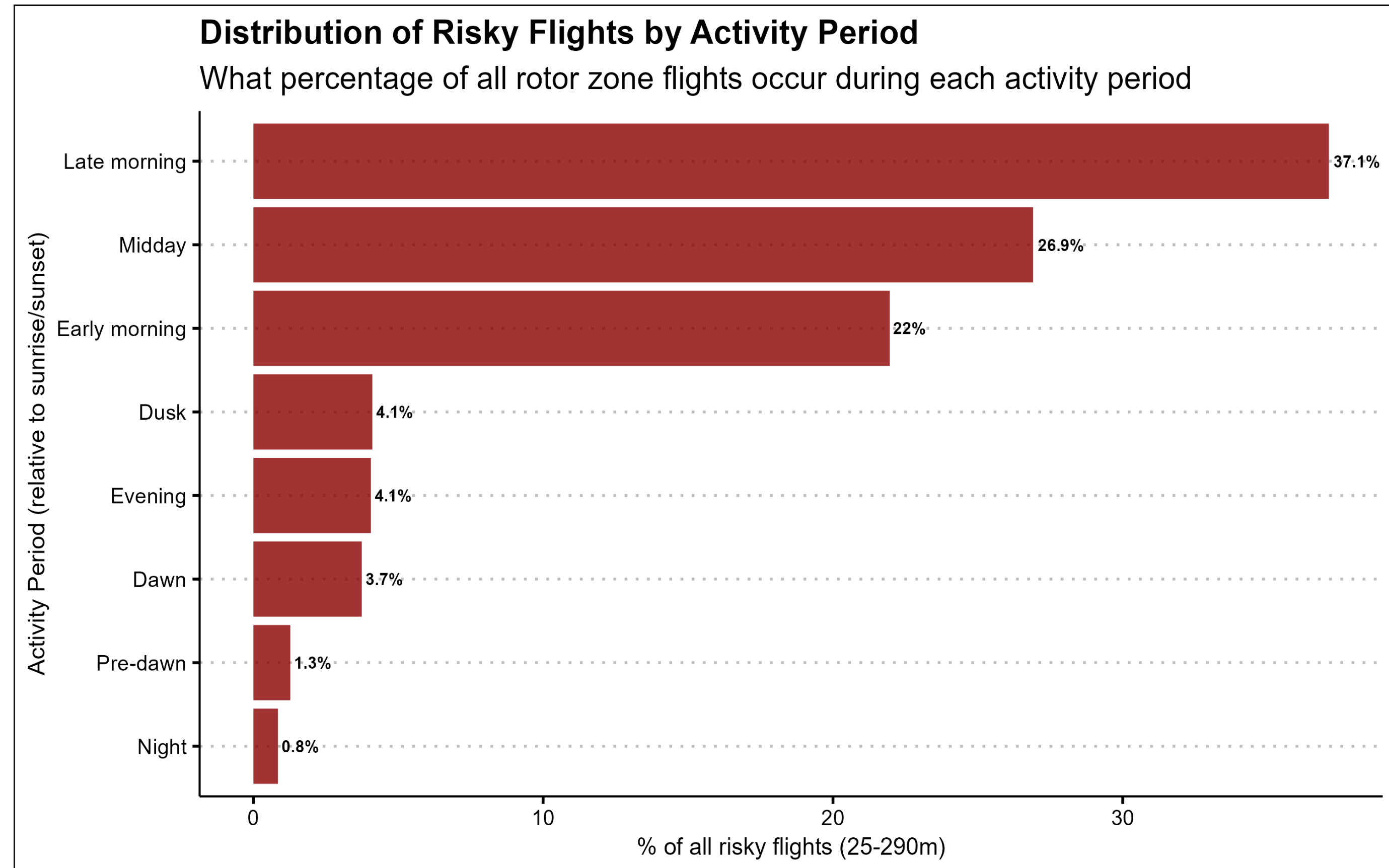
B. Temporal flight risk modelling

Peak Risk Periods:

Combined morning activity accounts for **59% of all rotor zone exposure.**

~30% of all risky flights could be missed in early summer depending on SDOD schedule.

Combined morning-midday activity accounts for **86% of all rotor zone exposure.**



Results

B. Temporal flight risk modelling

Deployed environment:

Precision = 0.92

Recall = 0.90

F1 = 0.91

Independent test:

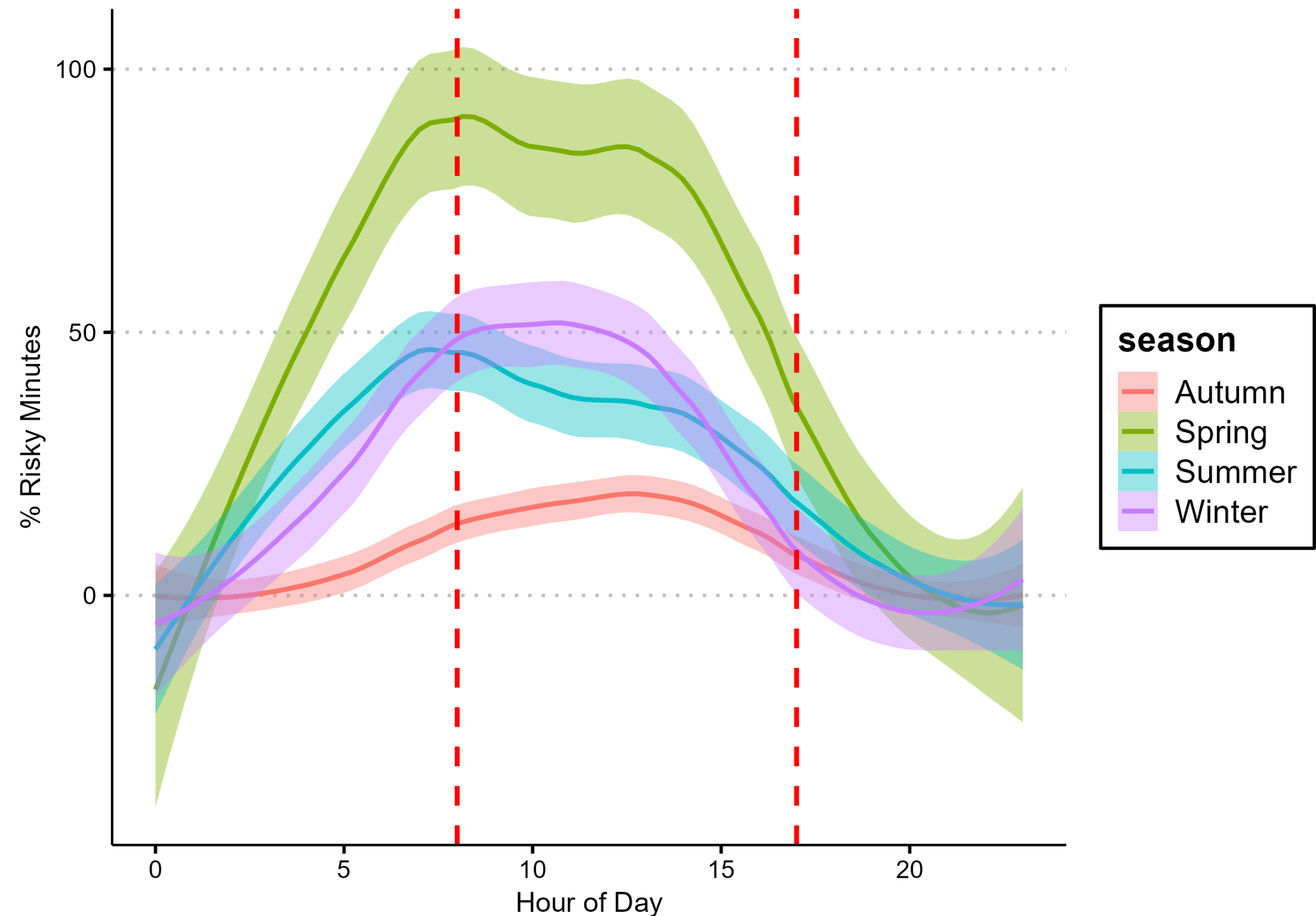
30% false positive rate.

0.1% false negative rate.

Key Predictive Variables:

- Distance to roost.
- Wind conditions (speed and direction).
- Temporal factors: seasonality and time of day.

Hourly Flight Risk by Season



Management Applications

From Prediction to Prevention

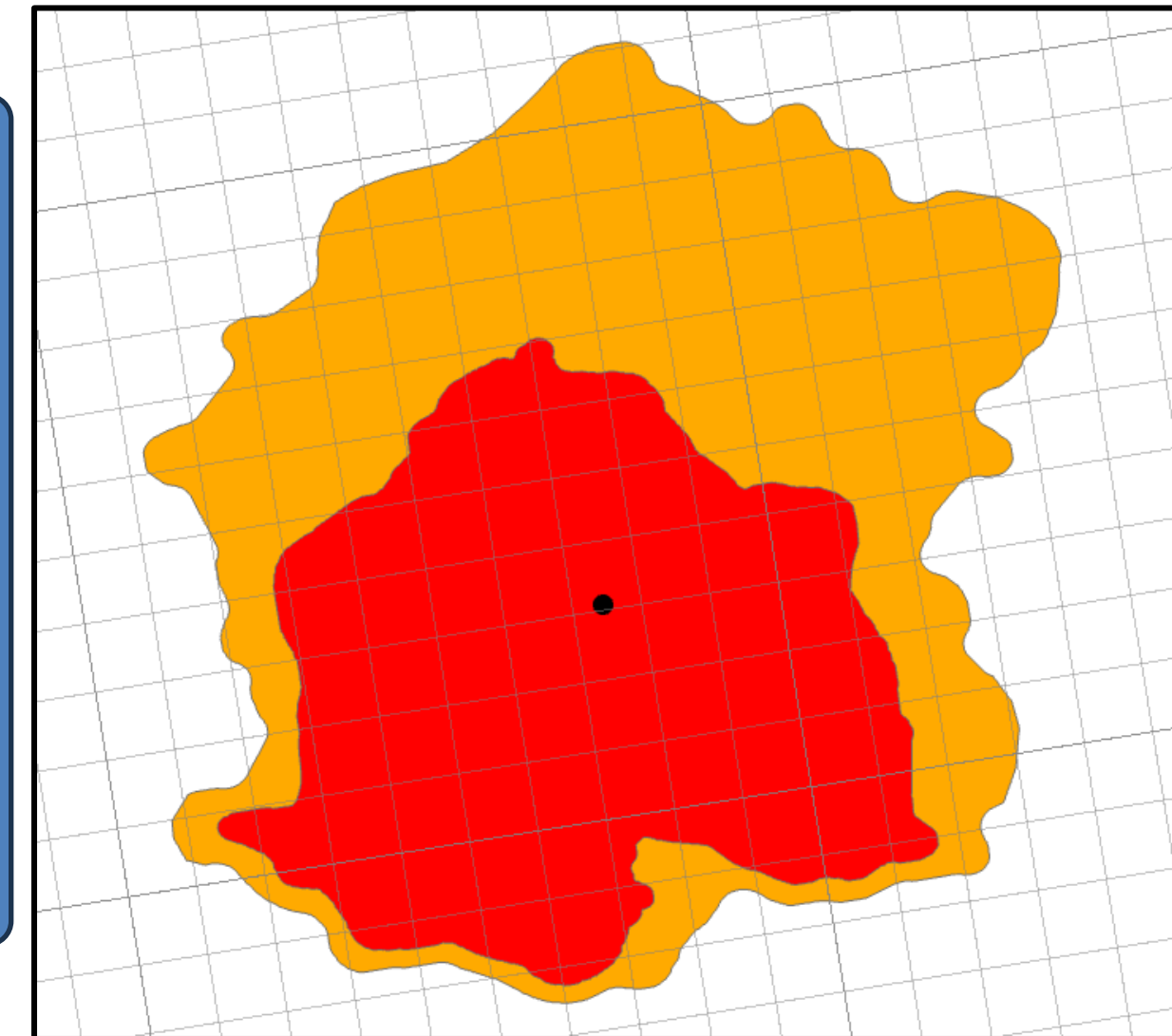
Pre-construction (Spatial Models):

- **Micro-siting:** Adjust turbine placement - avoid high-risk zones.
- **Risk assessment:** Quantify collision probability for layouts.
- **Regulatory compliance:** Evidence-based impact assessments.

Operational (Temporal Models):

- **Smart curtailment:** Curtail turbines during high-risk periods.
- **Adaptive monitoring:** Focus observer effort at high-risk times.
- **Risk management:** Extend protection beyond typical daylight hours.

Processed FRM



Thank You.



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