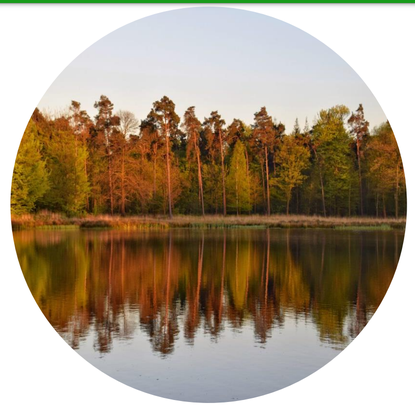
Hiding in plain sight

Unobserved reservoirs and future scenarios for Usutu virus transmission in the Netherlands

M.M. de Wit, G. Beaunée, M. Dellar, L. Krol, E. Münger, N. Atama, J. van Irsel, H. van der Jeugd, M. Koopmans, M.C.M. de Jong, R. Sikkema, Q. ten Bosch



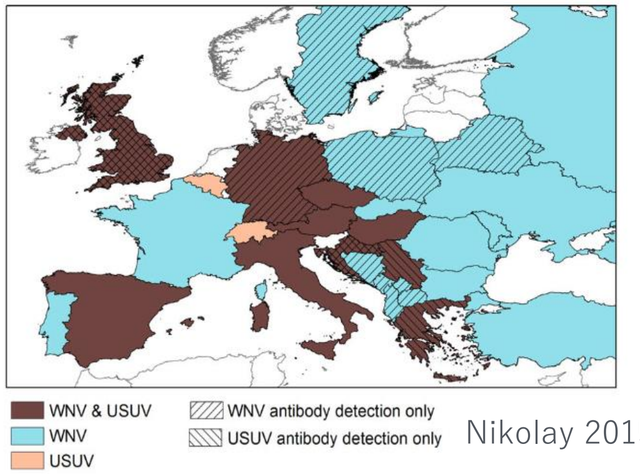
ModAH 2024

Speaker: Mariken de Wit mariken.dewit@wur.nl

WAGENINGEN
UNIVERSITY & RESEARCH

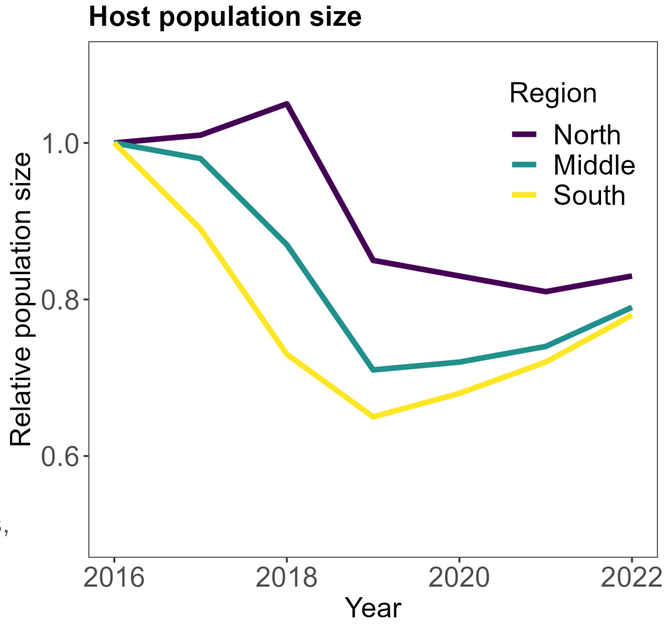
Usutu and West Nile virus

- Transmitted between birds and mosquitoes
- Antigenetically similar
- Overlapping host range: 34 bird species that can get infected with both
- Overlapping vector range: most frequently detected in *Culex pipiens* mosquitoes Nikolay 2015.



Nikolay 2015.

- WNV: larger impact in humans and horses
- Usutu: blackbirds most severely affected



Monitoring Scheme Breeding Birds, Sovon, Dutch Centre for Field Ornithology

Nikolay, B, A review of West Nile and Usutu virus co-circulation in Europe: how much do transmission cycles overlap?, Transactions of The Royal Society of Tropical Medicine and Hygiene, Volume 109, Issue 10, October 2015, Pages 609–618.

Usutu virus in the Netherlands

Observed emergence phase:

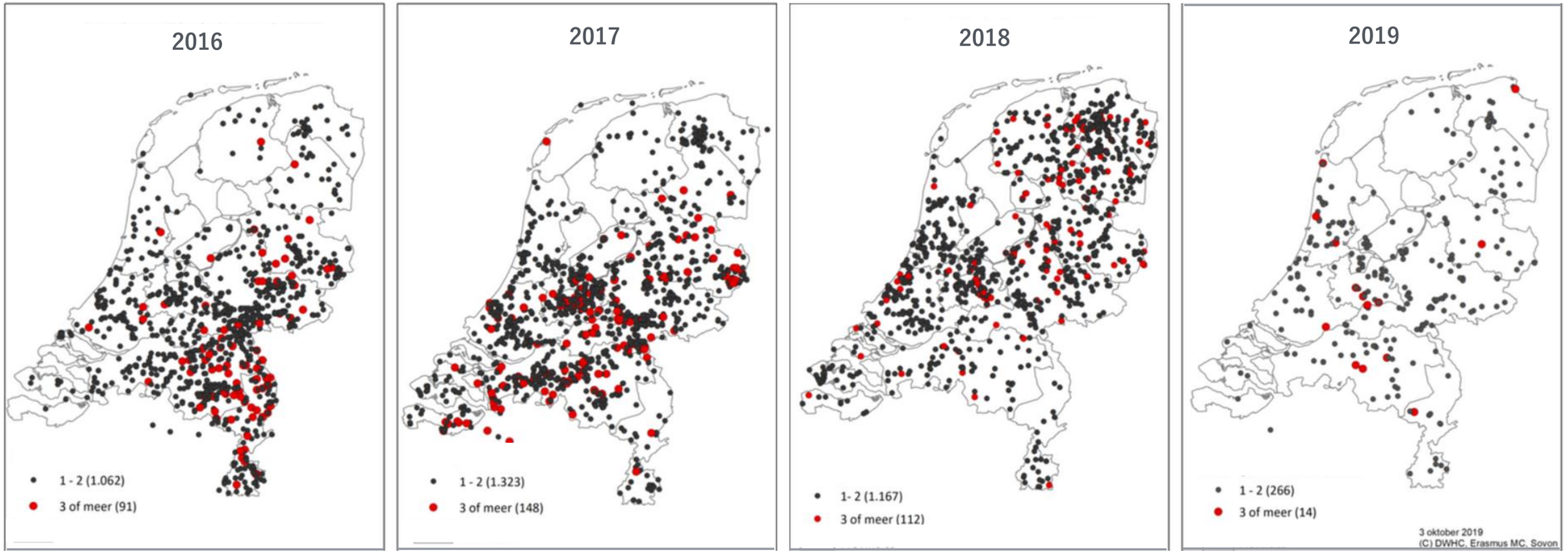
Rapid communication

Widespread Usutu virus outbreak in birds in the Netherlands, 2016 | Check for updates

JM Rijks[1,2] , ML Kik[1,2,3] , R Slaterus[4] , RPB Foppen[4,5] , A Stroo[6] , J IJzer[1,3] , J Stahl[4] , A Gröne[1,3] , MGP Koopmans[7] , HP van der Jeugd[8] , CBEM Reusken[7]

Eurosurveillance, 2016

Number of reported dead blackbirds



Maps from:
Montizaan M, et al. Nature Today [Internet]. 2019 https://www.naturetoday.com/intl/nl/nature-reports/message/?msg=25571

Data collected by:
Monitoring Scheme Dead Birds, Sovon, Dutch Centre for Field Ornithology

Usutu virus in the Netherlands

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Widespread Usutu virus outbreak in birds in the Netherlands, 2016

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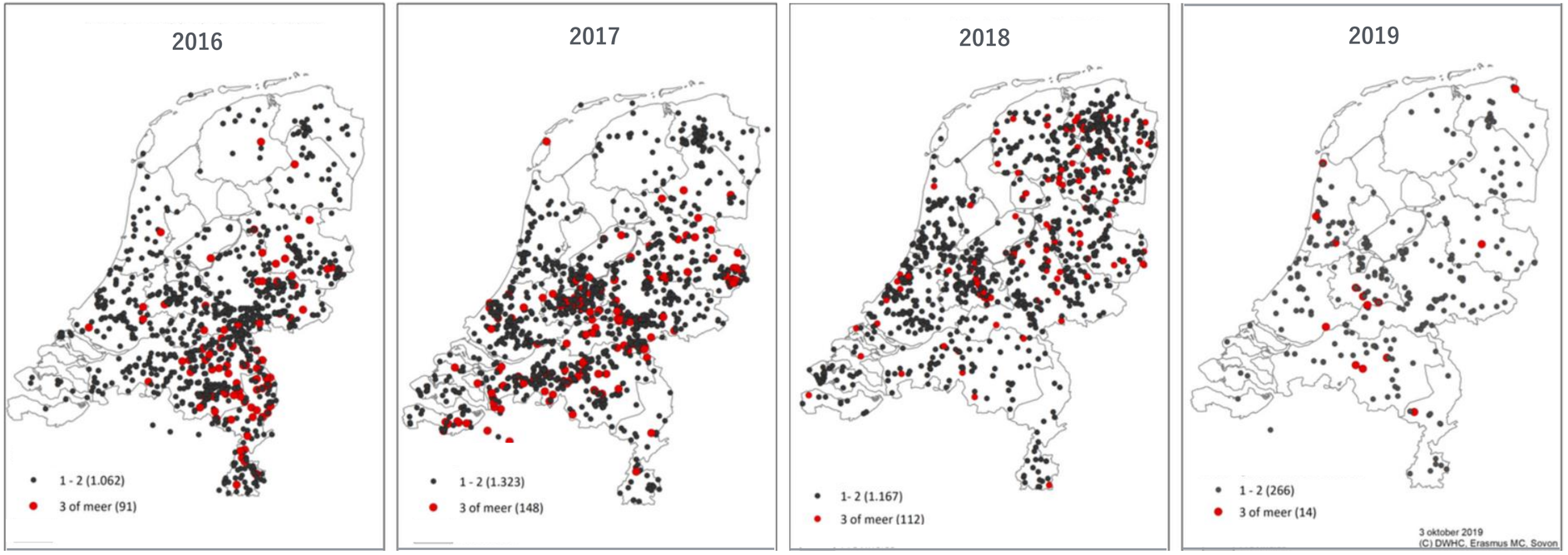
Eurosurveillance, 2016

Multiple wildlife surveillance schemes:

- Reported dead birds
- PCR dead birds
- PCR live birds
- Serology live birds
- Bird population trends

Number of reported dead blackbirds



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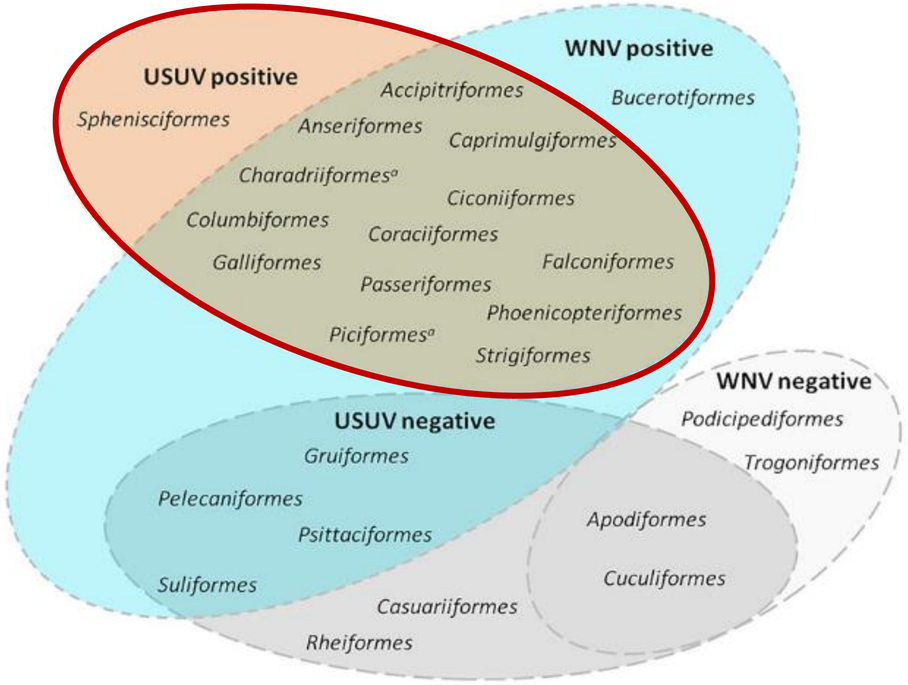
Data collected by:
Monitoring Scheme Dead Birds, Sovon, Dutch Centre for Field Ornithology

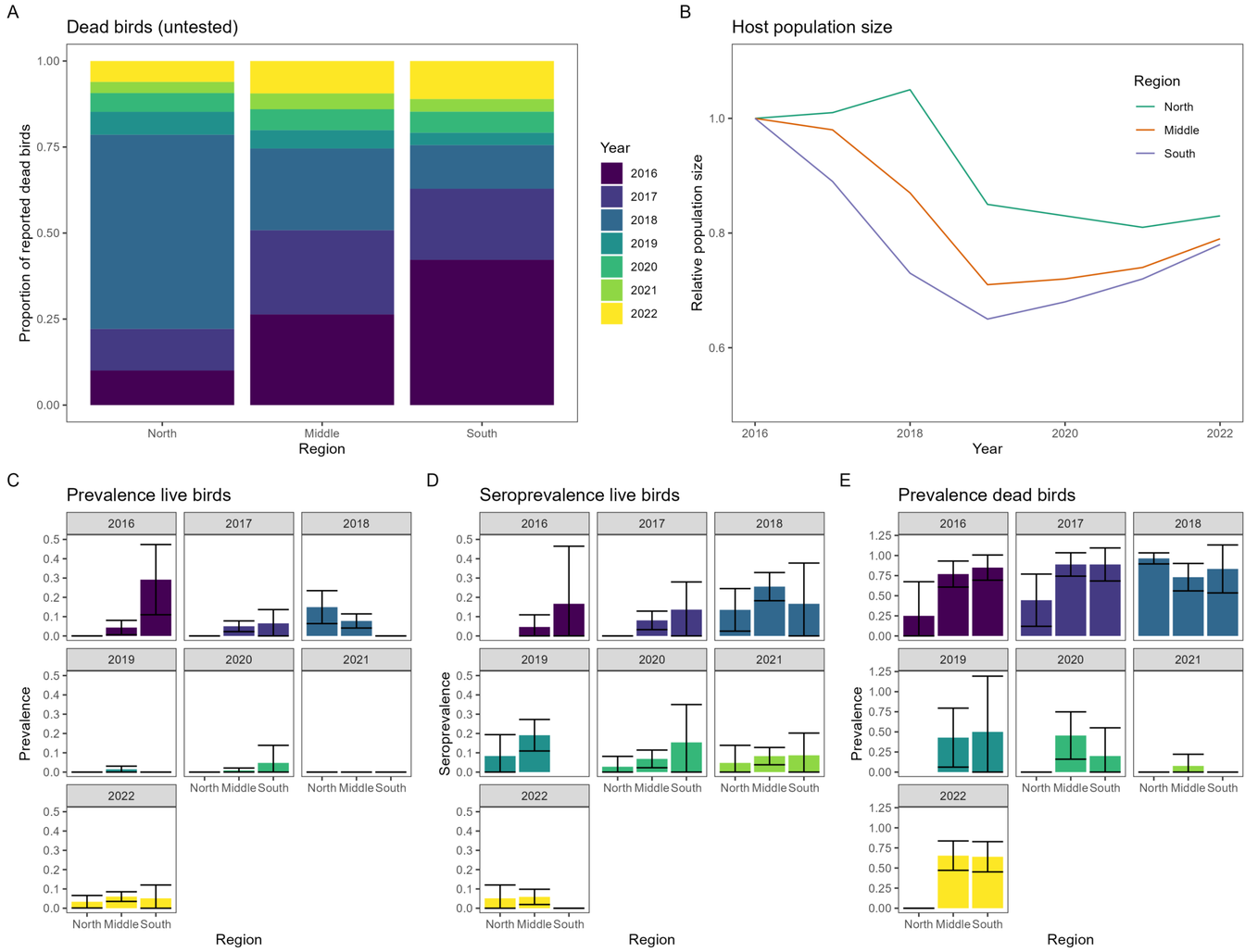
Is the main victim solely responsible for transmission?

Angeloni G. et al. Epidemiology, surveillance and diagnosis of Usutu virus infection in the EU/EEA, 2012 to 2021. Euro Surveill. 2023;28(33)



Nikolay, B, A review of West Nile and Usutu virus co-circulation in Europe: how much do transmission cycles overlap?, Transactions of The Royal Society of Tropical Medicine and Hygiene, Volume 109, Issue 10, October 2015, Pages 609–618.

Leveraging wildlife surveillance data



Virus spreads from South to North in three years

Transmission reduced after 2018

Model structure

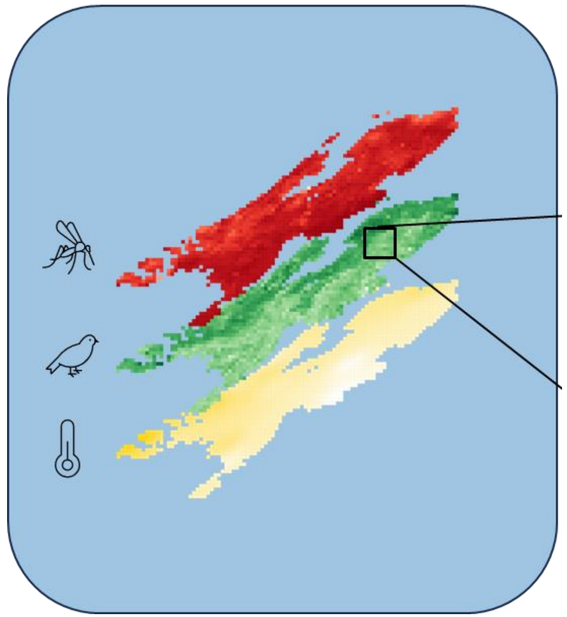
Transmission model

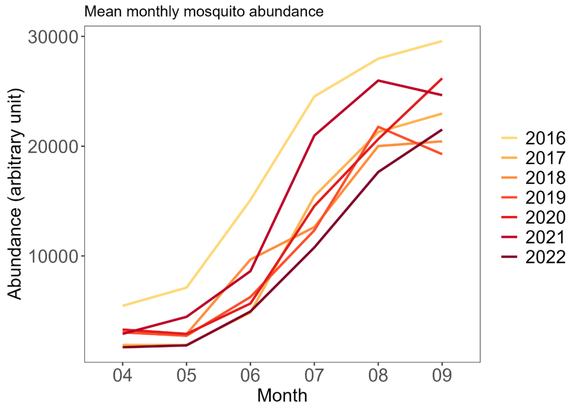
Population dynamics

Abundance

Diapause

Model input layers

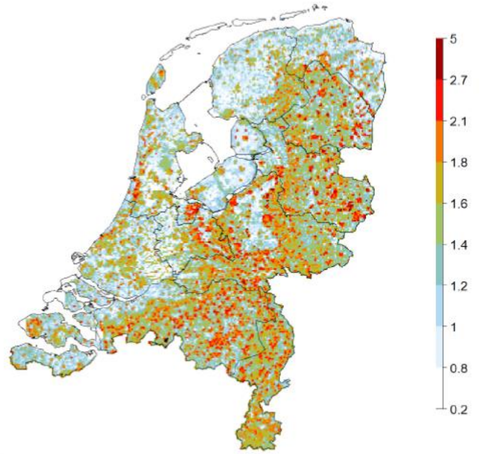




Data: trap counts

Ibañez-Justicia, A., et al. National mosquito (Diptera: Culicidae) survey in the Netherlands 2010–2013. Journal of Medical Entomology 52.2 (2015): 185-198.

Van Bortel, W, et al. MODIRISK: Mosquito vectors of disease, collection, monitoring and longitudinal data from Belgium. Gigabyte2022 (2022): 1-15.



Data: blackbird point counts

NL: Meetnet Urbane Soorten & Meetnet Agrarische Soorten

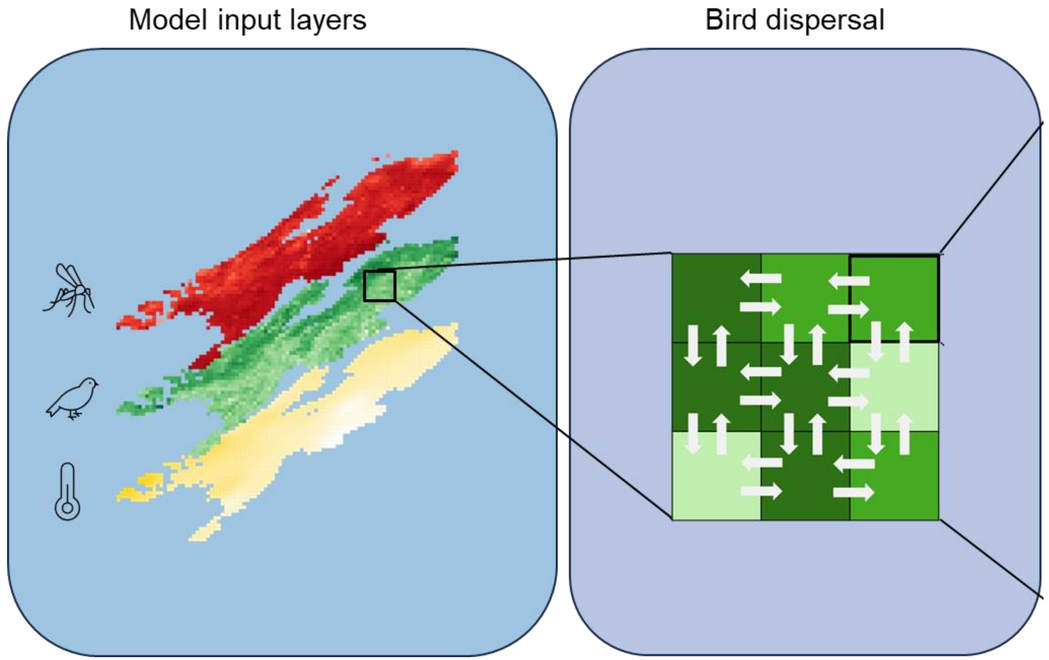
FR: Common Bird Monitoring Scheme

Sovon

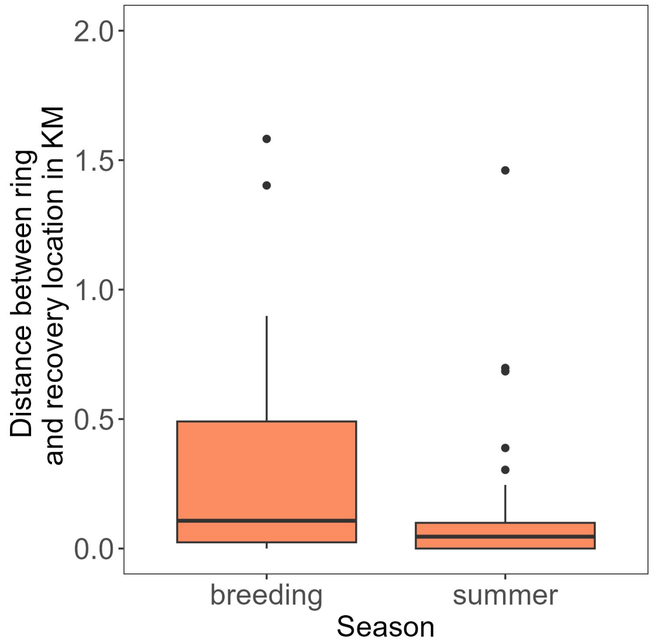
Transmission model

Bird movement

Daily dispersal (breeding vs non-breeding season)
Natal/breeding dispersal
No mosquito movement



5x5km

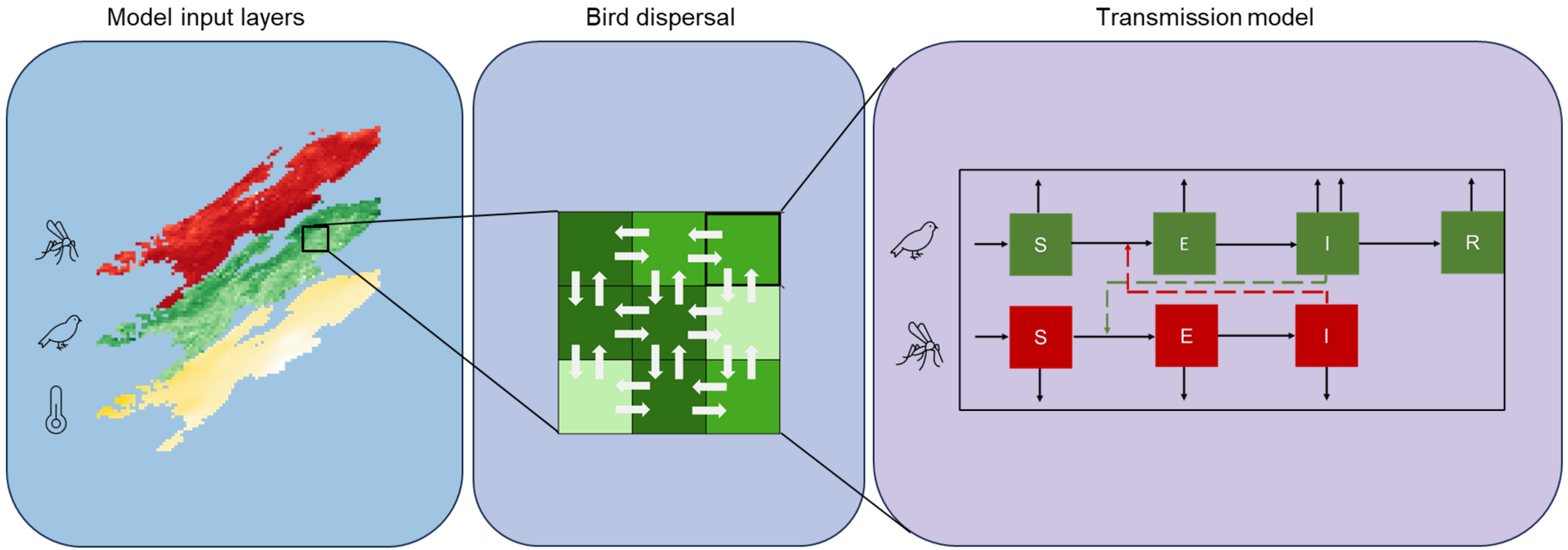


Data: Vogeltrekstation NIOO-KNAW ringing and dead recoveries of blackbirds in the Netherlands

Transmission model

Infection dynamics

Biting rate & extrinsic incubation period & mosquito mortality

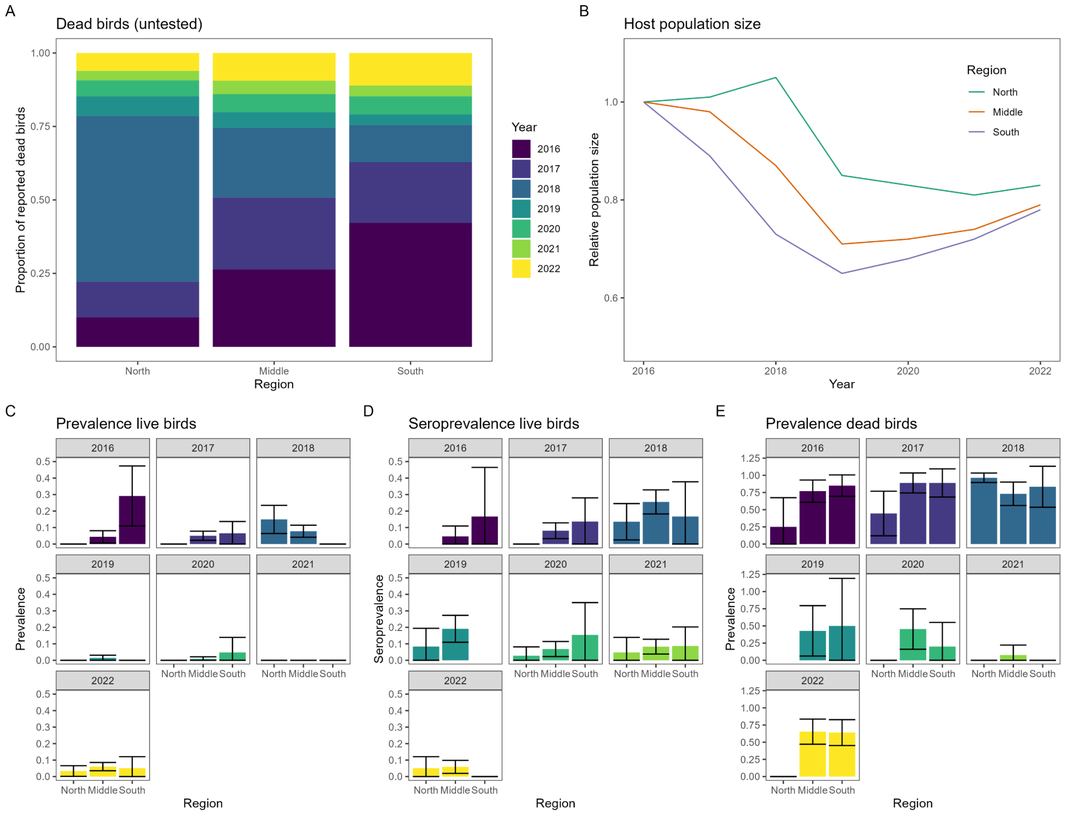


Inference

Model calibration

Approximate Bayesian Computation with SMC sampler

- Calibration to multiple aspects of outbreak by using several types of blackbird surveillance data
- Use of summary statistics from full datasets
- Incorporate observation process when known



Toni, T., et al. Approximate Bayesian computation scheme for parameter inference and model selection in dynamical systems. J Roy Soc Interface 6, 187–202 (2009).

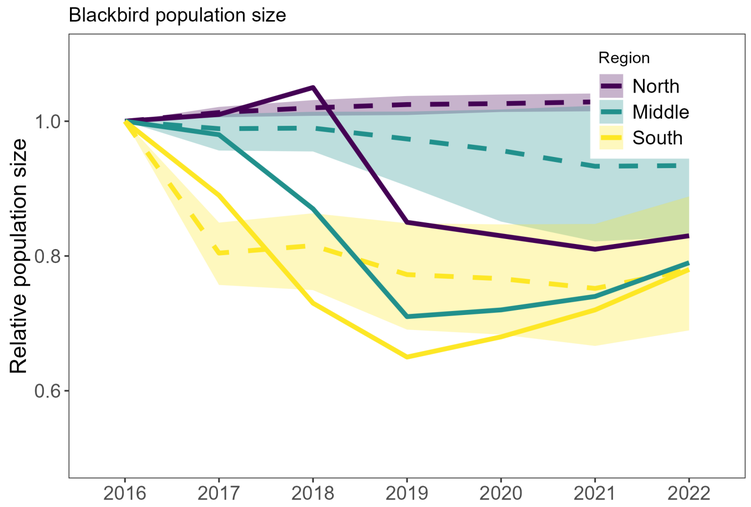
Filippi, S., et al. On optimality of kernels for approximate Bayesian computation using sequential Monte Carlo. Stat Appl Genet Mol 12, 87–107 (2013).

Beaunée, G. BRREWABC R-package

Results

Comparing model versions visually

A. Blackbird only



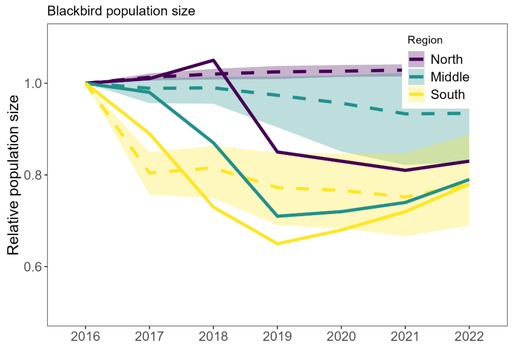
Model output

Observed data

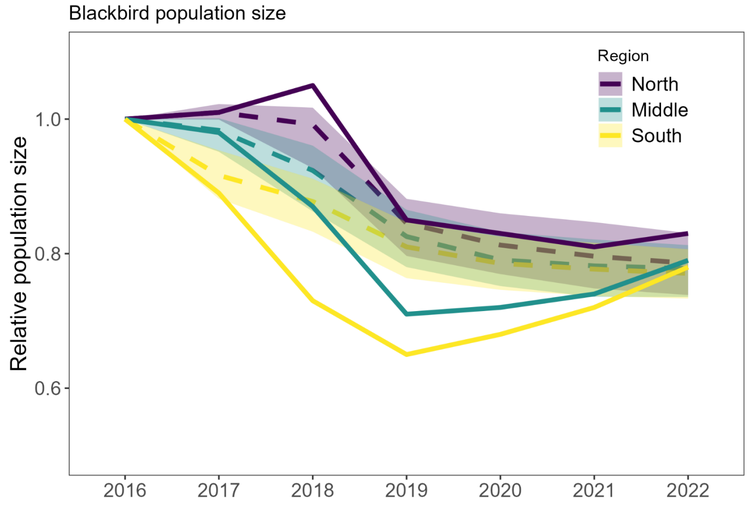
Data sources: Monitoring Scheme Breeding Birds, Sovon, Dutch Centre for Field Ornithology

Comparing model versions visually

A. Blackbird only



B. Blackbird & high-disperser



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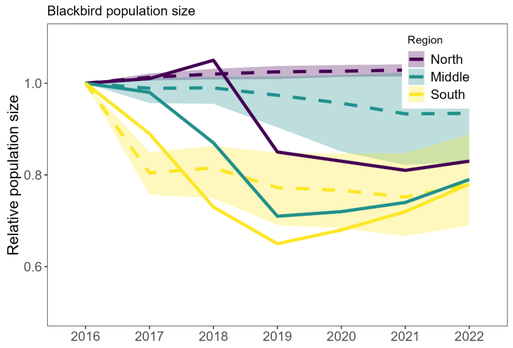

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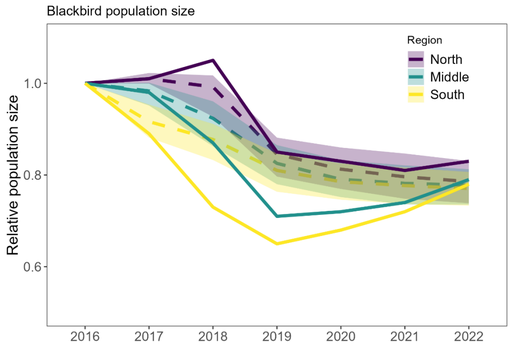
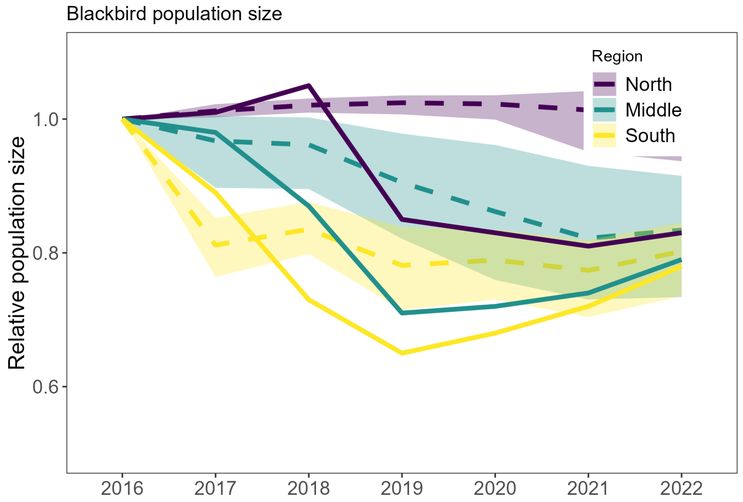


C. Blackbird & no Usutu mortality & estimated adult lifespan



one health pact

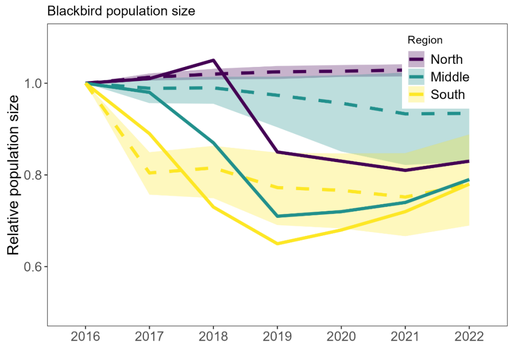
Model output

Observed data

Data sources: Monitoring Scheme Breeding Birds, Sovon, Dutch Centre for Field Ornithology

Comparing model versions visually

A. Blackbird only



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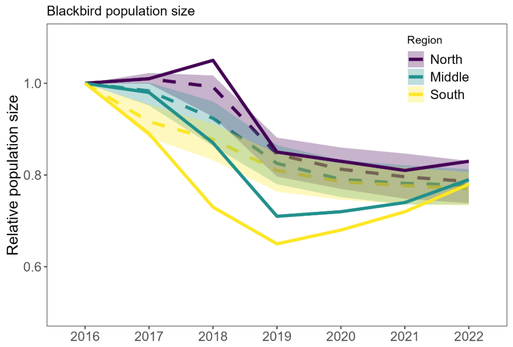
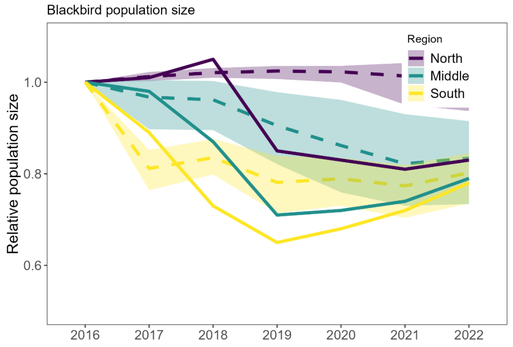
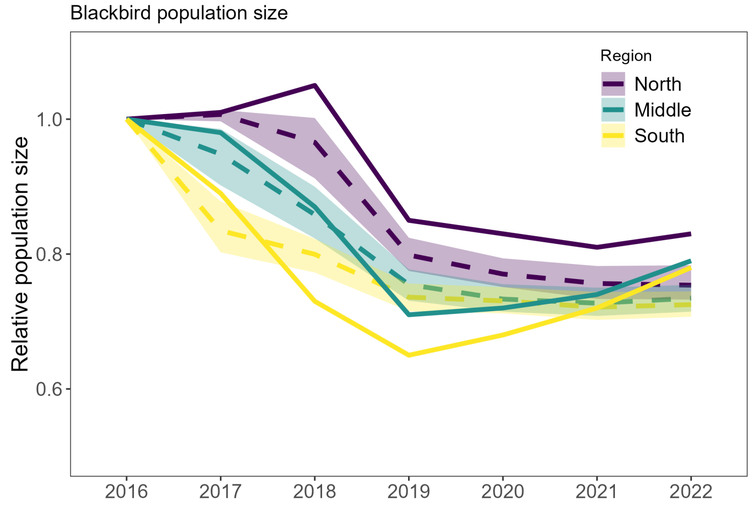


C. Blackbird & no Usutu mortality & estimated adult lifespan



D. Blackbird & high-dispersal & no Usutu mortality & estimated adult lifespan



one health pact

Model output

Observed data

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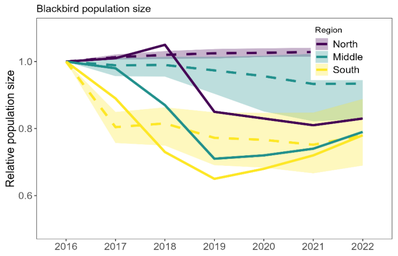
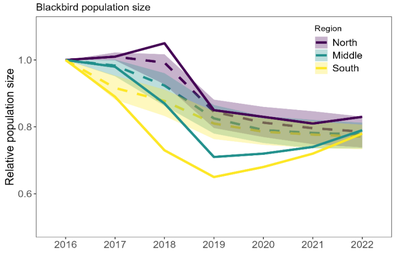
Comparing model versions quantitatively

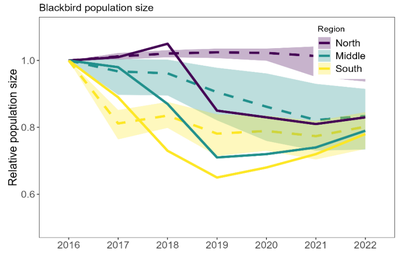
A. Blackbird only



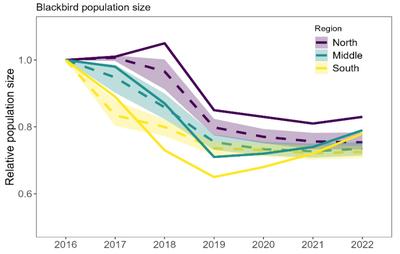
B. Blackbird & high-disperser

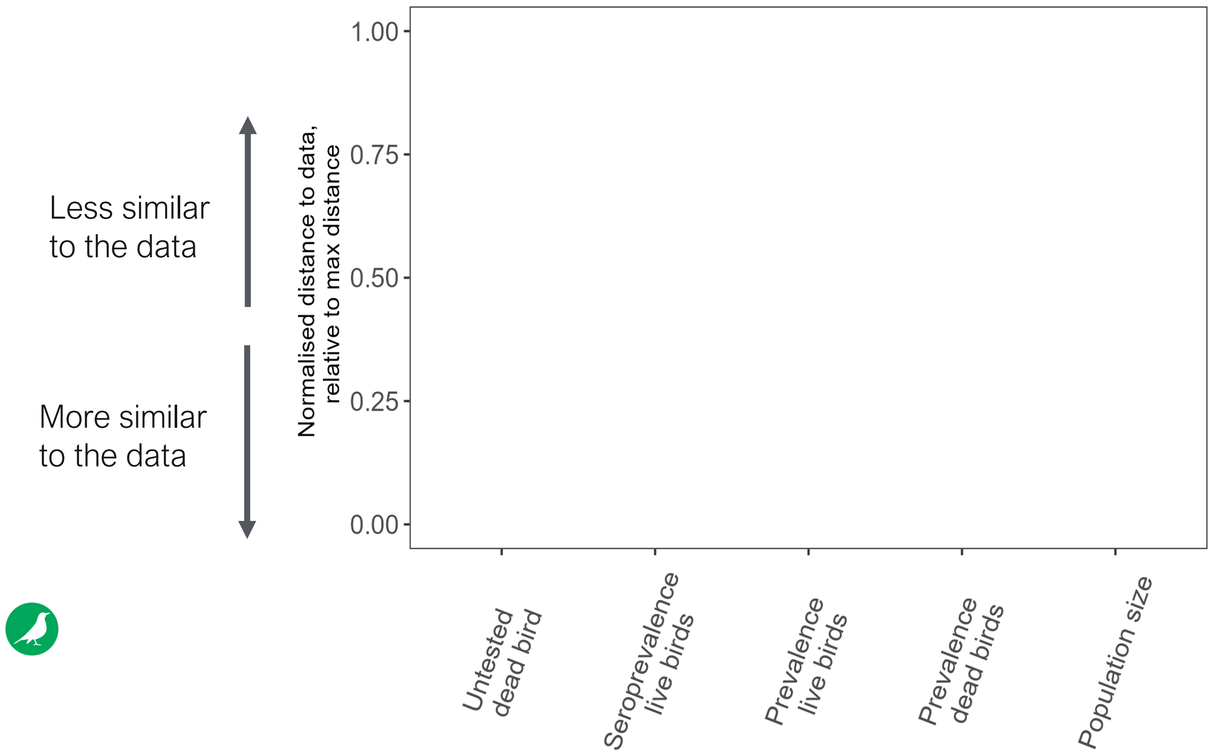


C. Blackbird & no Usutu mortality & estimated adult lifespan



D. Blackbird & high-dispersal & no Usutu mortality & estimated adult lifespan



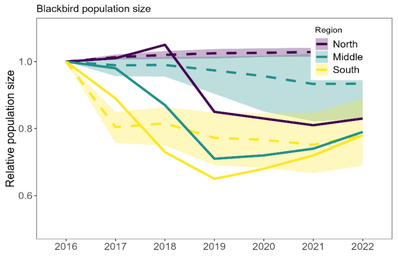


A: Blackbird only
B: Reservoir host: increased dispersal
C: Reservoir host: no infection mortality & estimated lifespan
D: Reservoir host: increased dispersal & no infection mortality & estimated lifespan

one health pact

Comparing model versions quantitatively

A. Blackbird only



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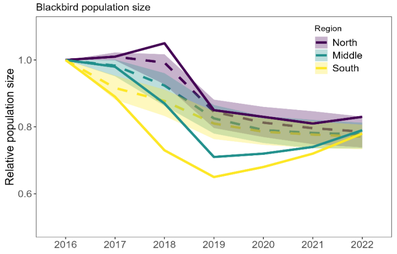
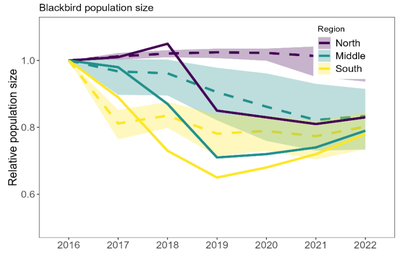
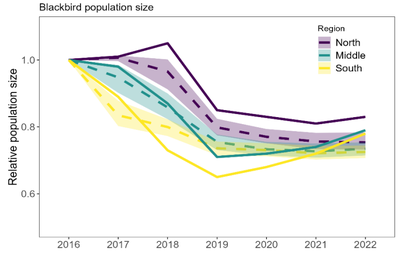


C. Blackbird & no Usutu mortality & estimated adult lifespan

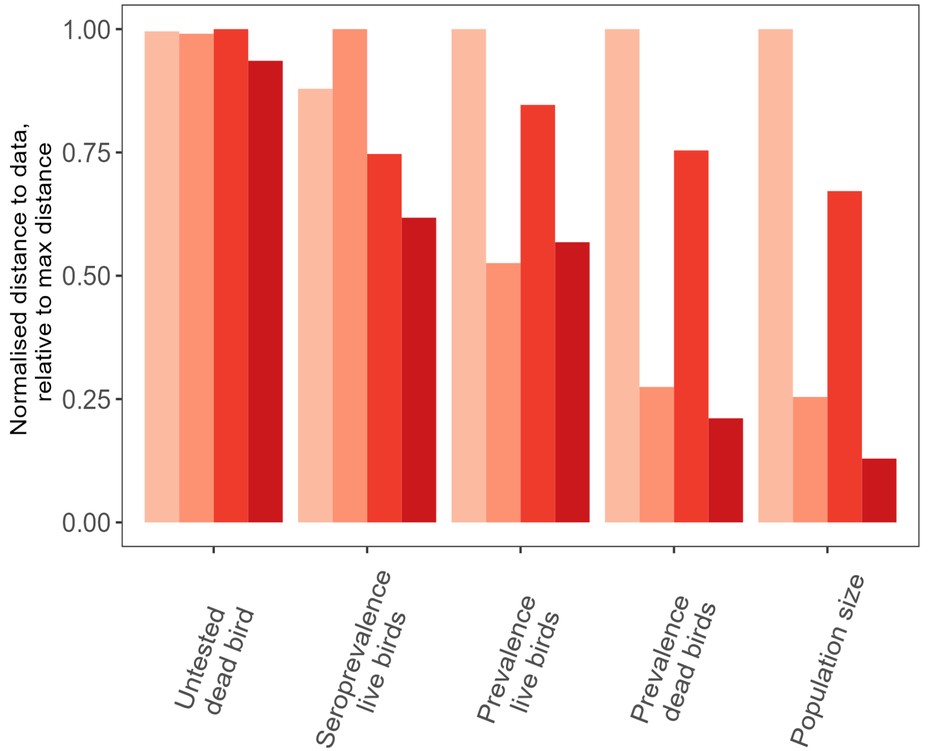


D. Blackbird & high-dispersal & no Usutu mortality & estimated adult lifespan



Less similar to the data

More similar to the data



A: Blackbird only
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D: Reservoir host: increased dispersal & no infection mortality & estimated lifespan

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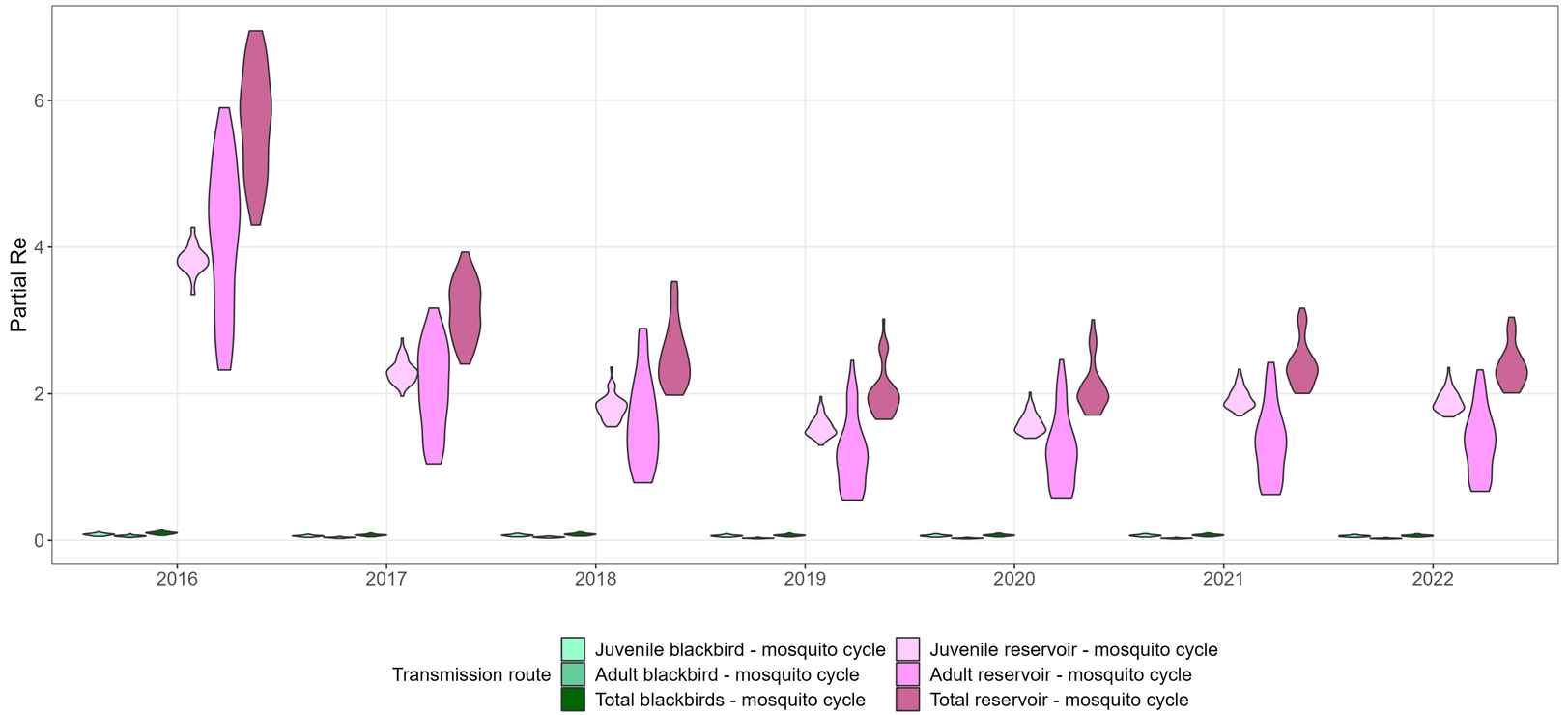
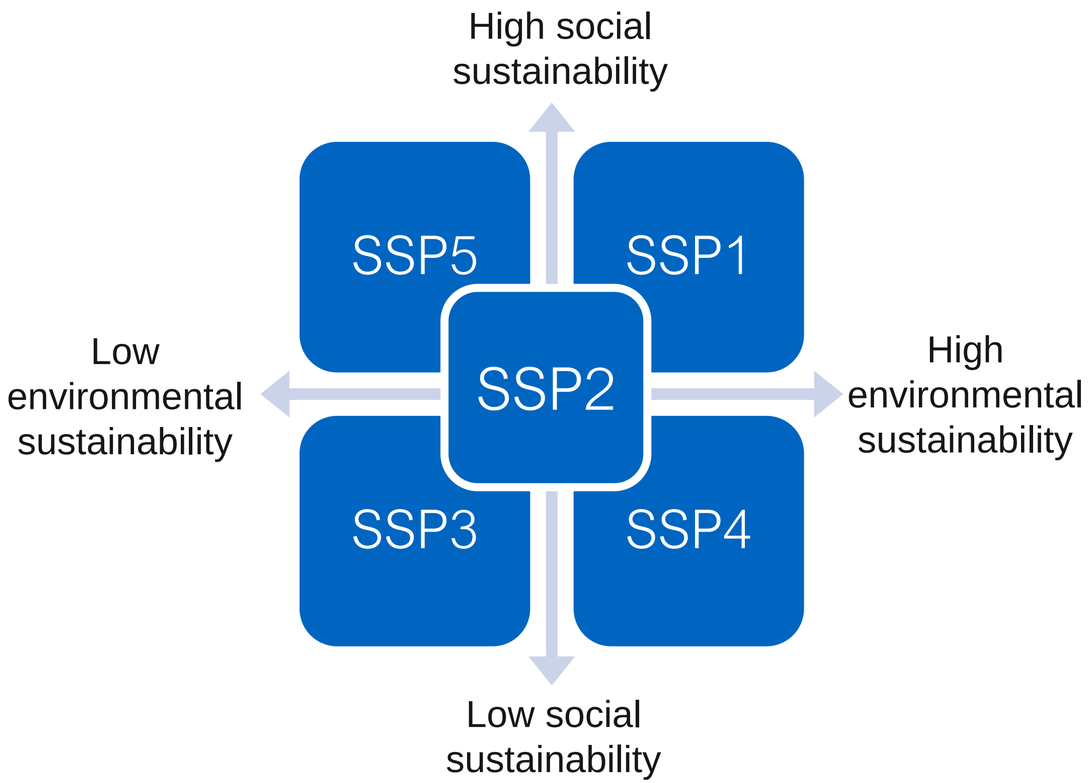
Contributions from reservoir population



So much for the past - what about the future?

Future scenarios: Shared Socio-economic Pathways



‘One Health’ scenarios	Demographics Economy & Technology Land use Inequality Environment Governance Agriculture Lifestyles Health & Healthcare

one health pact

Creating Dutch One Health SSPs

Global / European SSPs

Survey

2 workshops

Dutch One Health SSPs

Existing Dutch scenarios

Expert interviews

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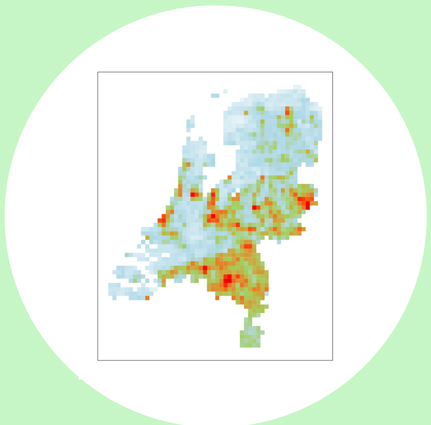
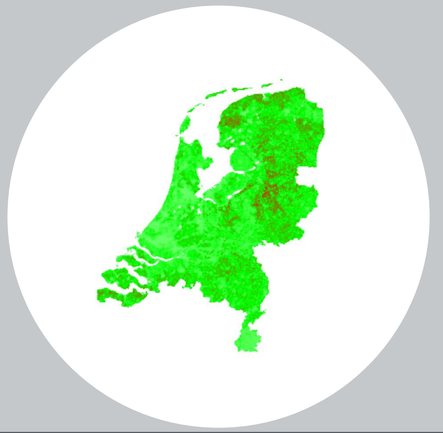
Future scenarios: Shared Socio-economic Pathways

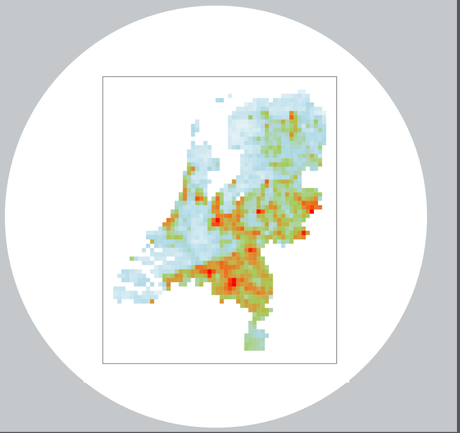
LOW	**Extreme weather events**	LOW/MEDIUM
LOW	**Pollution**	HIGH
LOW	**Threats to biodiversity**	HIGH
LOW	**Animal welfare issues**	HIGH

Dellar, M., Geerling, G., Kok, K. *et al.* Creating the Dutch One Health Shared Socio-economic Pathways (SSPs). *Reg Environ Change* **24**, 16 (2024). https://doi.org/10.1007/s10113-023-02169-1

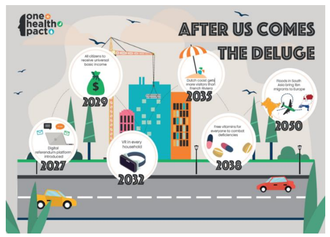
From SSP to transmission risk

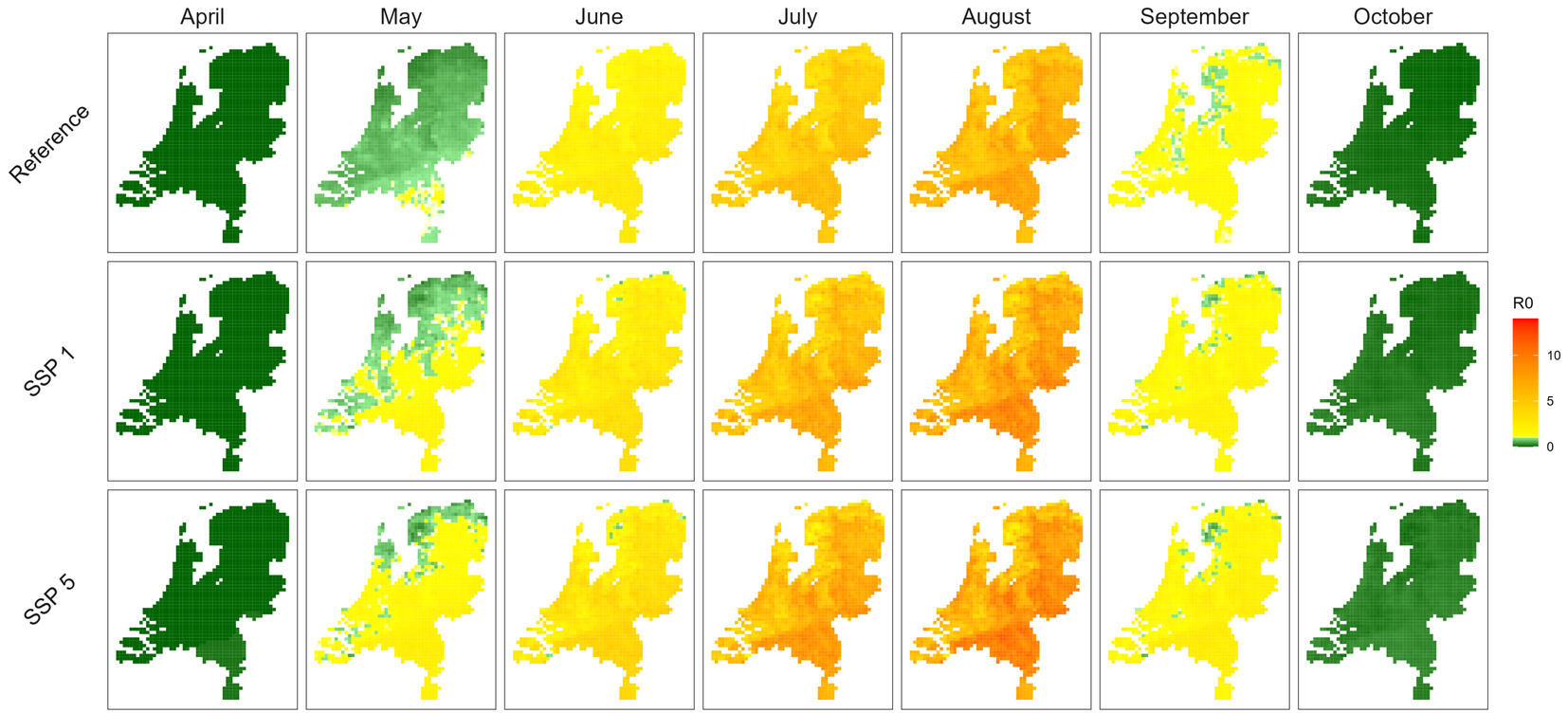






Impact of future scenarios on transmission risk





Conclusion

Conclusion

Although blackbirds are most severely affected, blackbirds alone can not explain the observed spread of Usutu virus.

Other (bird) species, that **disperse further** than blackbirds and **develop more immunity**, contributed significantly to Usutu virus transmission.

Risk and size of Usutu virus outbreaks is expected to increase in possible future scenarios.

Hiding in plain sight:

Martha Dellar

Louie Krol

one health pact

Quirine ten Bosch

Mart de Jong

Powered by:

Henk van der Jeugd

Gaël Beaunée

NWO

netherlands centre for one health

Erasmus MC

Radboudumc university medical center

Universiteit Leiden

WAGENINGEN UNIVERSITY & RESEARCH

LUMC

Deltares Enabling Delta Life

Koninklijk Nederlands Meteorologisch Instituut Ministerie van Infrastructuur en Waterstaat

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Stichting [Technasium]

UMC Utrecht

Nederlandse Voedsel- en Warenautoriteit Ministerie van Landbouw, Natuur en Voedselkwaliteit

National Institute for Public Health and the Environment Ministry of Health, Welfare and Sport

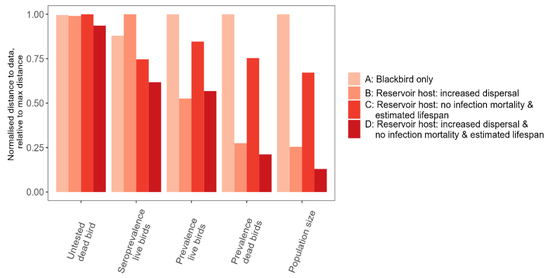
CEAB exploring aquatic ecosystems

Rode Kruis

Sovon

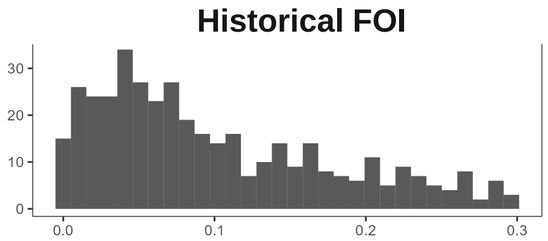
Extra slides

Characterising the unobserved reservoir

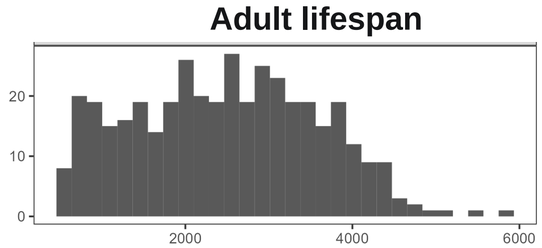


Limited mortality from infection

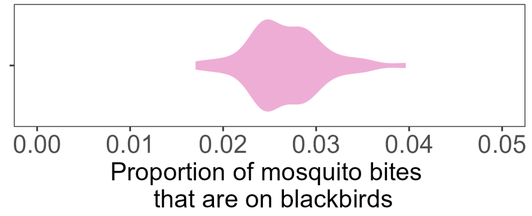
Further dispersal than best estimate for blackbirds



Little to no immunity from prior transmission



Longer lifespan than blackbirds
6.9 years (95%CI 1.6 – 11.8)



Around 35 times more bites than on blackbirds

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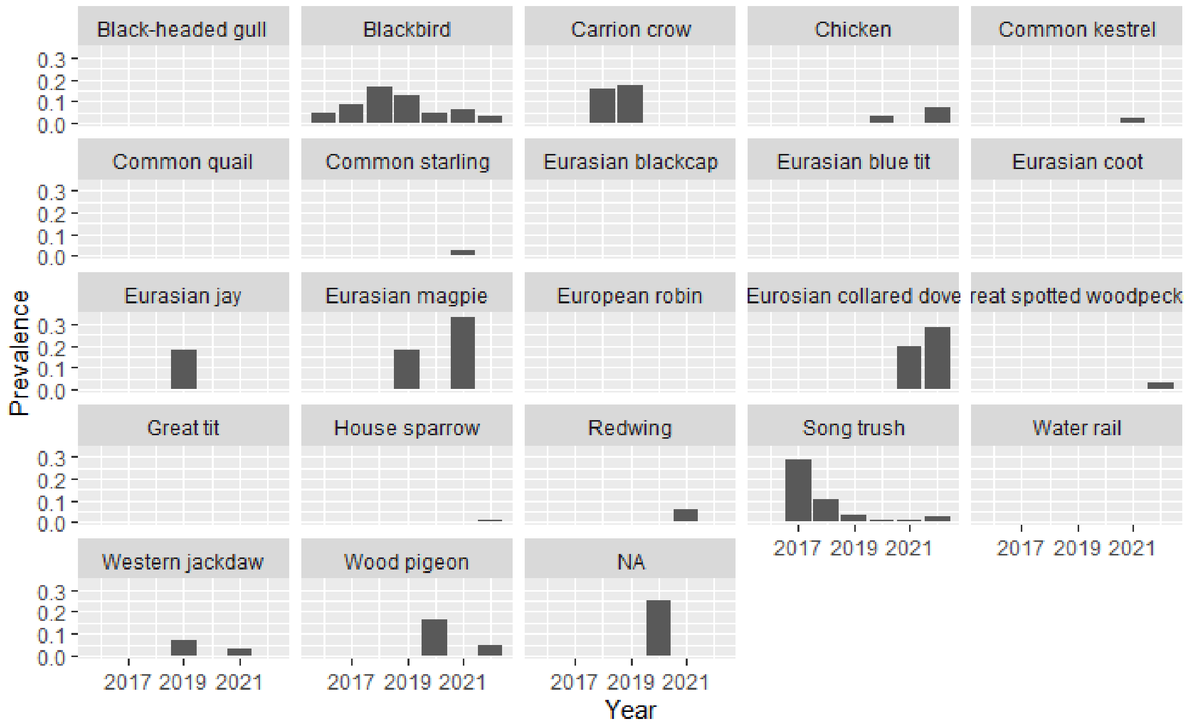
Reservoir species

Species with seroprevalence higher than blackbirds in NL surveillance or Austrian study by Meister et al. (2008)

Species	Adult lifespan
blackbirds,	3
blackcaps (*Sylvia atricapilla),*	2
long-eared owl (*Asio otus*),	4
doves *(Streptopelia decaocto),*	3
jackdaws *(Corvus monedula),*	5
robins *(Erithacus rubecula).*	2
crows *(Corvus corone),*	4
magpies *(Pica pica),*	5
song thrushes *(Turdus philomeus)*	3

Also experimental study

Estimate:
6.9 years (95%CI 1.6 – 11.8)



Model versions

Table 1: Specification of model versions

	Virus introduction	Host species	Characteristics other host species			
			Infection mortality ratio	Lifespan	Dispersal distance	Population distribution
A	South	Blackbird	NA	NA	NA	NA
B	South	Blackbird & other	Blackbird-like	Blackbird-like	Increased	Blackbird-like
C	South	Blackbird & other	Zero	Estimated	Blackbird-like	Blackbird-like
D	South	Blackbird & other	Zero	Estimated	Increased	Blackbird-like
Sensitivity analyses*						
S1	Everywhere	Blackbird & other	Zero	Estimated	Increased	Blackbird-like
S2	South	Blackbird & other	Zero	Estimated	Increased	Uniform
S3	South	Blackbird with alternative dispersal** & other	Zero	Estimated	Blackbird-like with alternative dispersal**	Blackbird-like

* Sensitivity analyses were based on model D, because this was the best-fitting model from options A-D.
** In the 'blackbird-like with alternative dispersal' scenario, post-breeding season movement was increased to equal breeding season movement.

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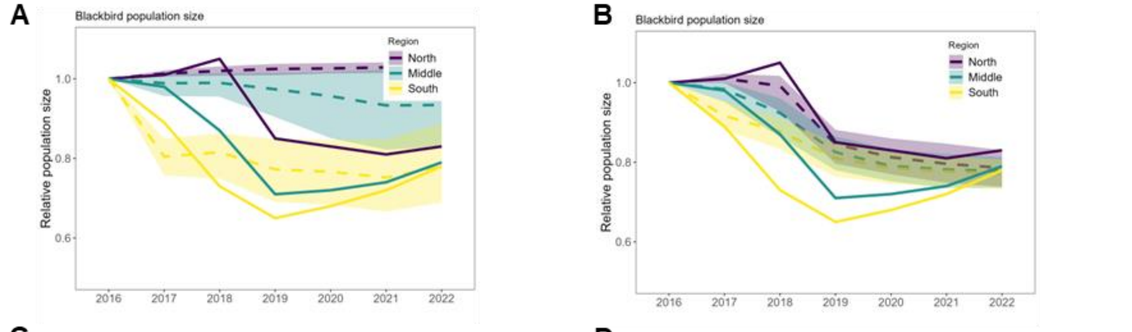
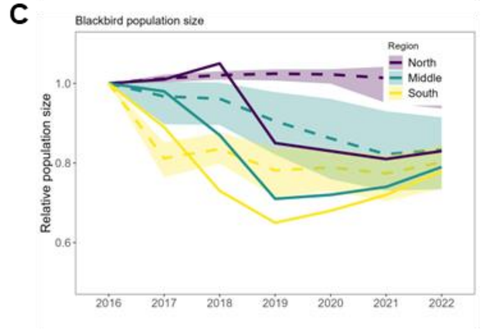
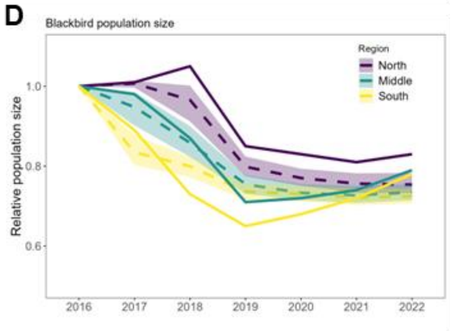
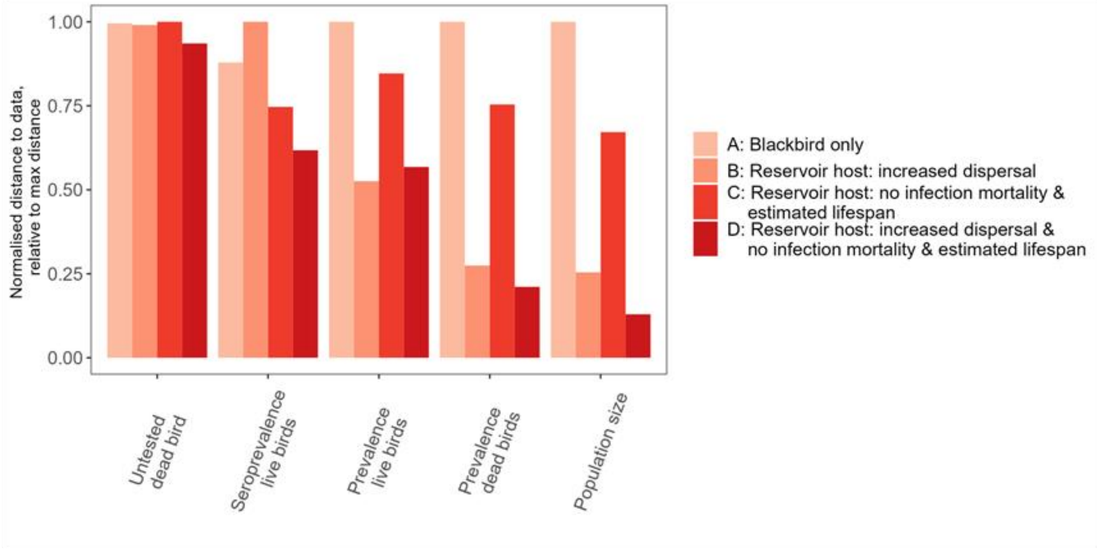
Characteristics additional host species

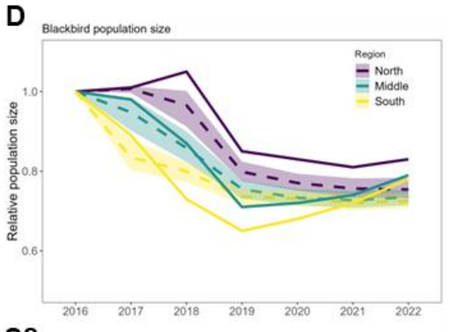


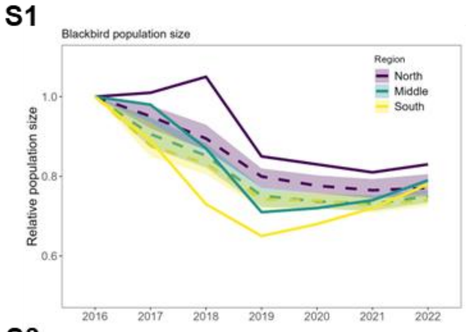


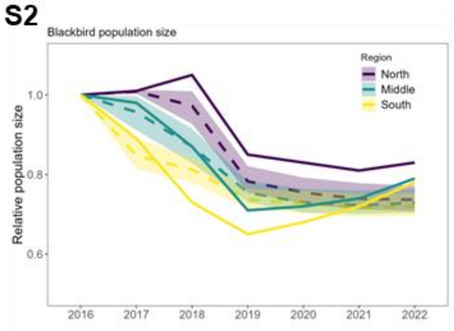


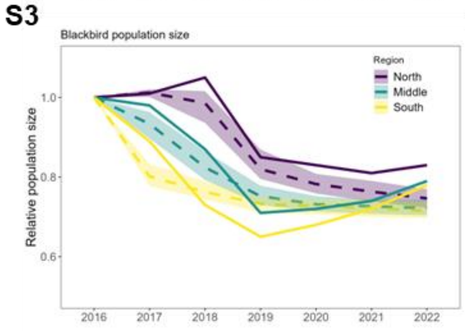


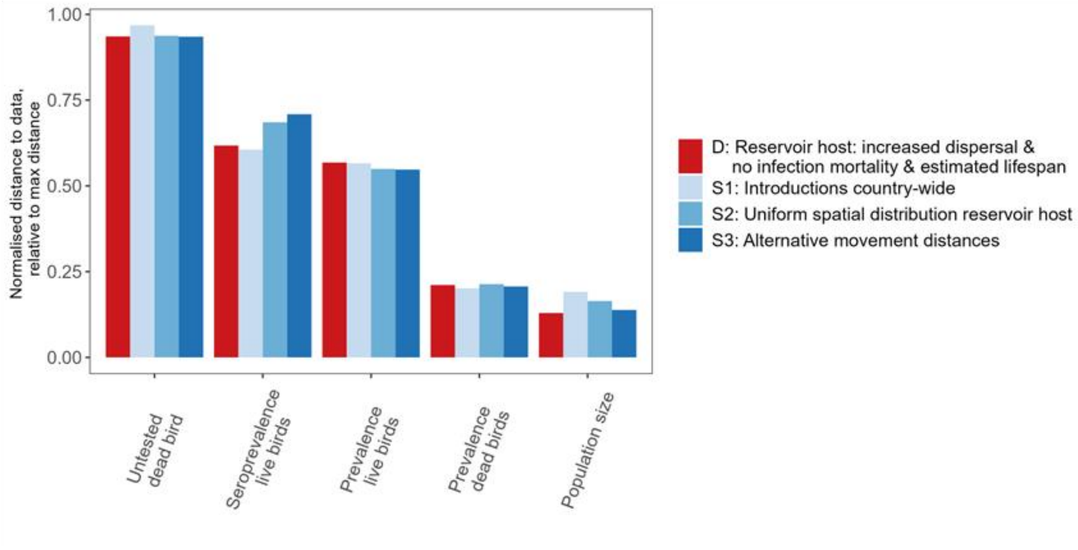
Sensitivity analyses



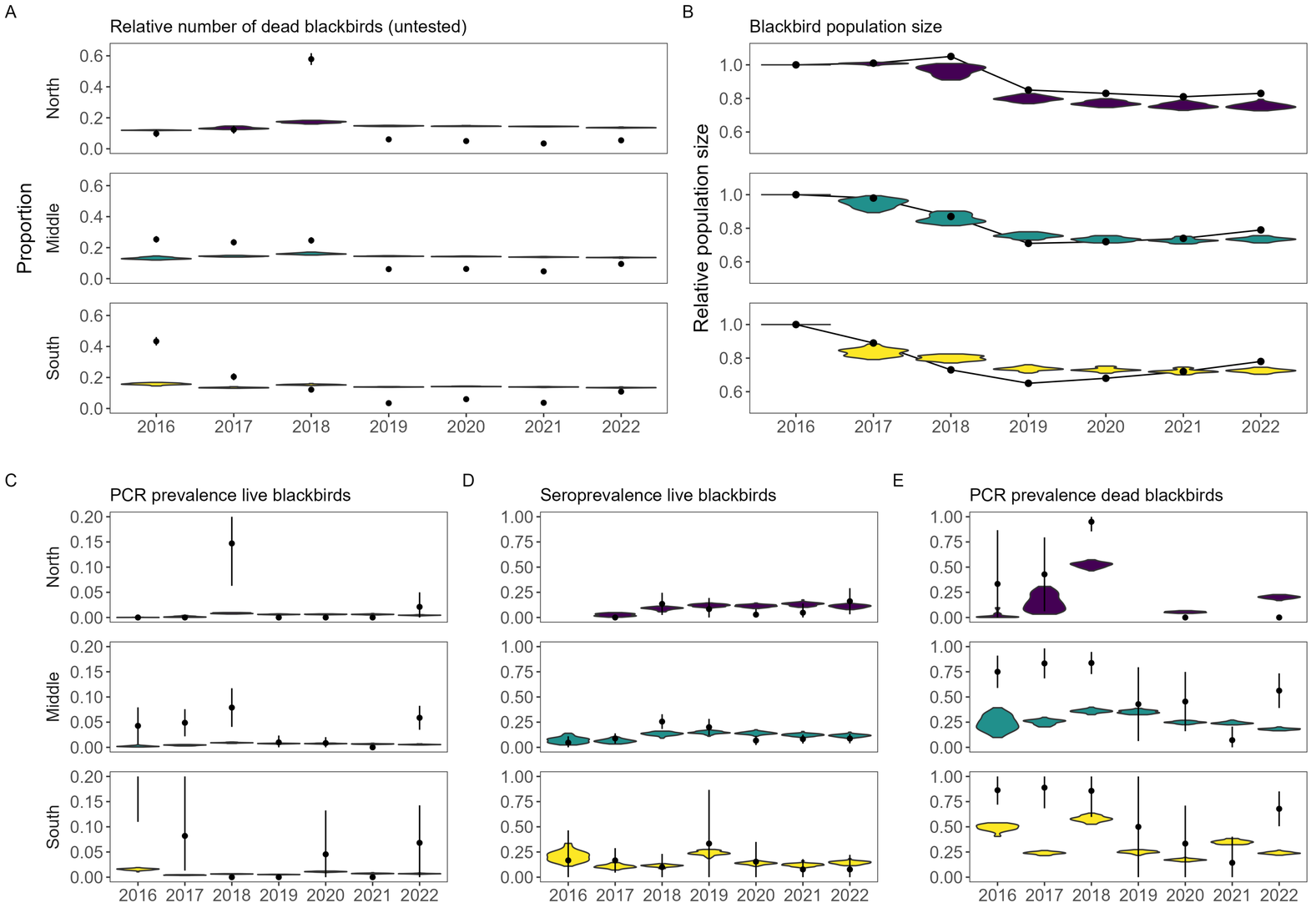








All fits



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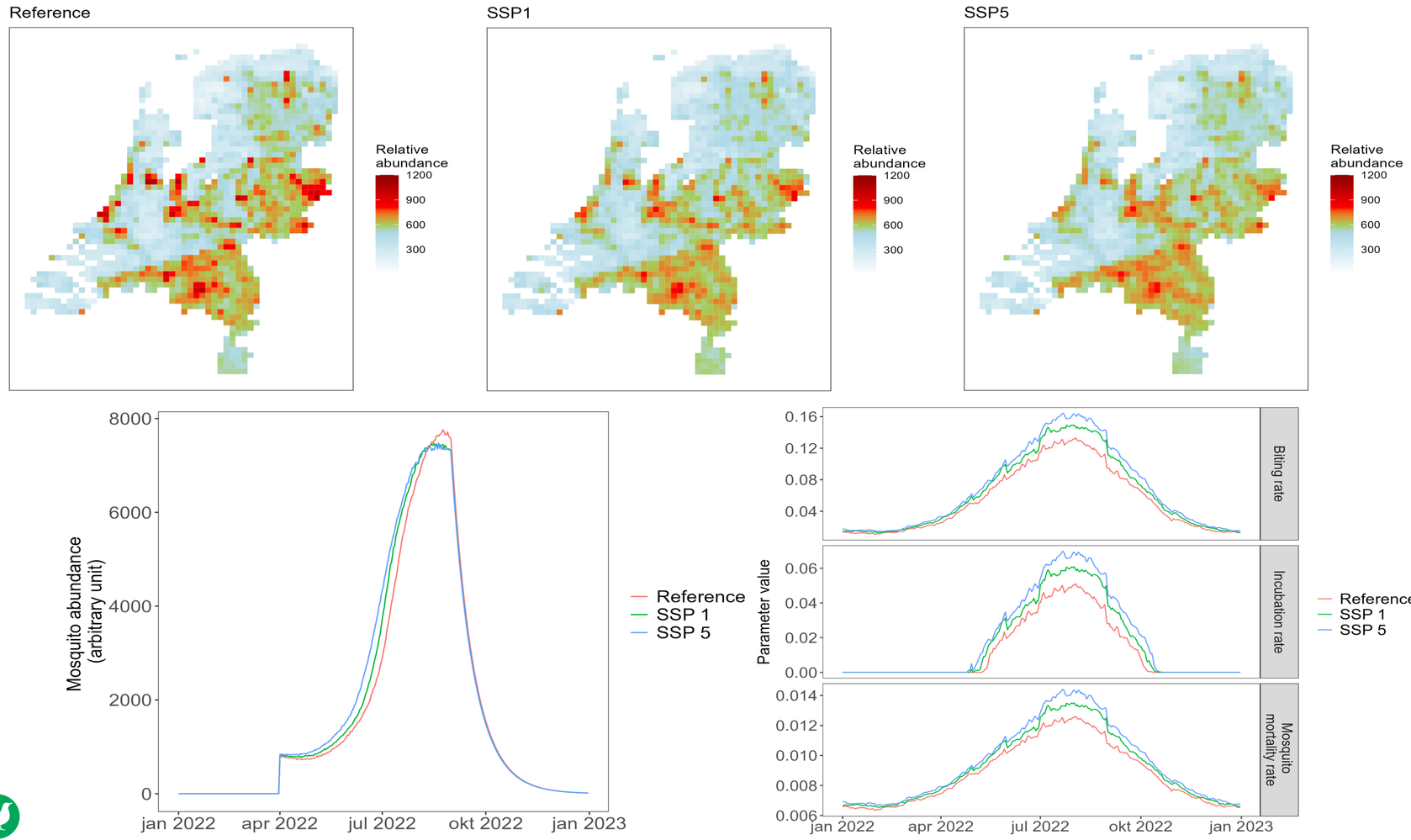
Scenario input