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The Effects of Cold:
Mosquito-borne Diseases under Changing Climate

Stephanie THOMAS

Department of Biogeography, University of Bayreuth, Germany

The Future of the Arctic
London, March 2014

1. Mosquitoes and the Arctic
2. Invasive mosquito vectors
3. Modelling areas at risk in the light of Climate Change
4. Low temperature survival of mosquito eggs
5. Conclusion

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Climate Change Research

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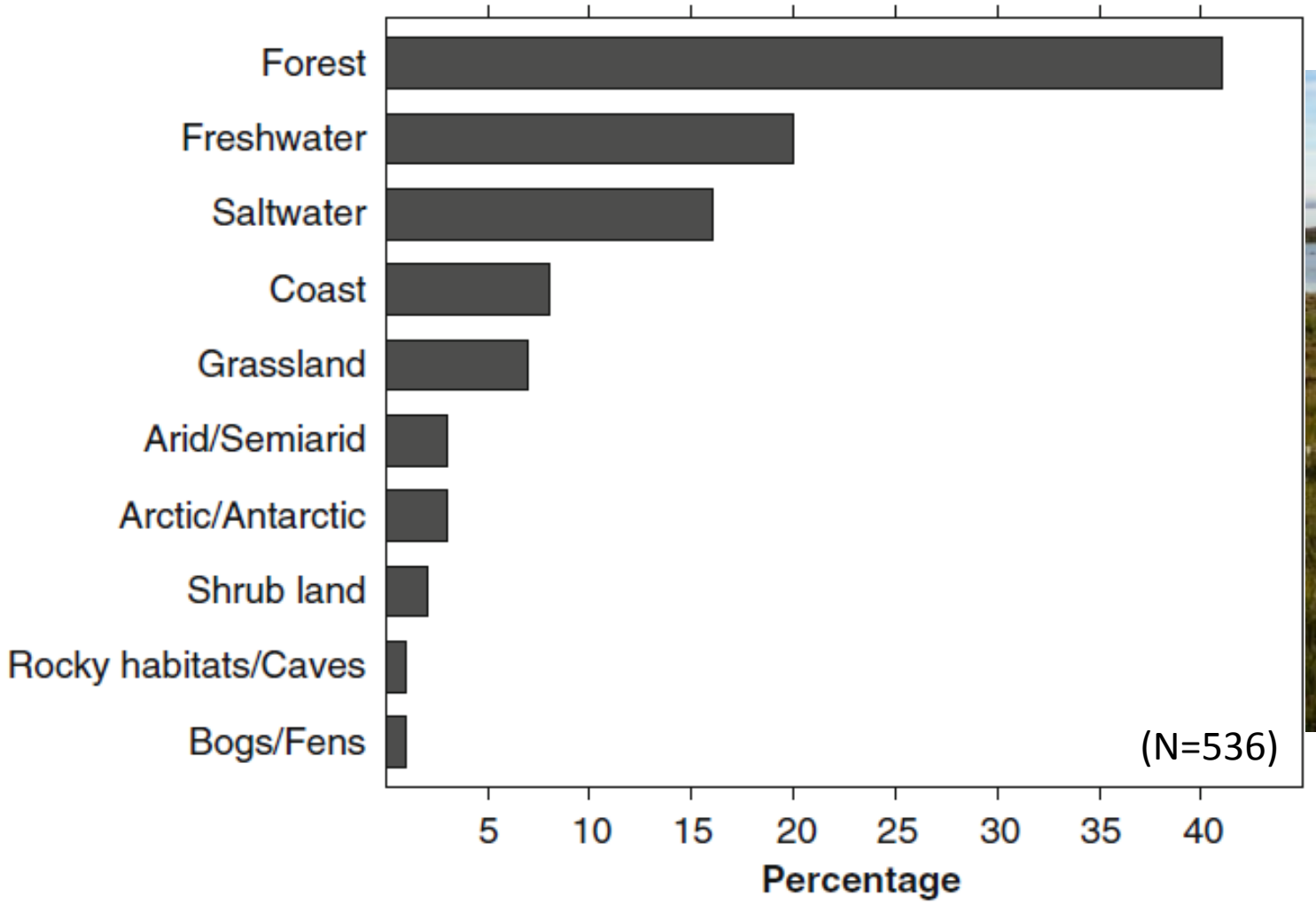
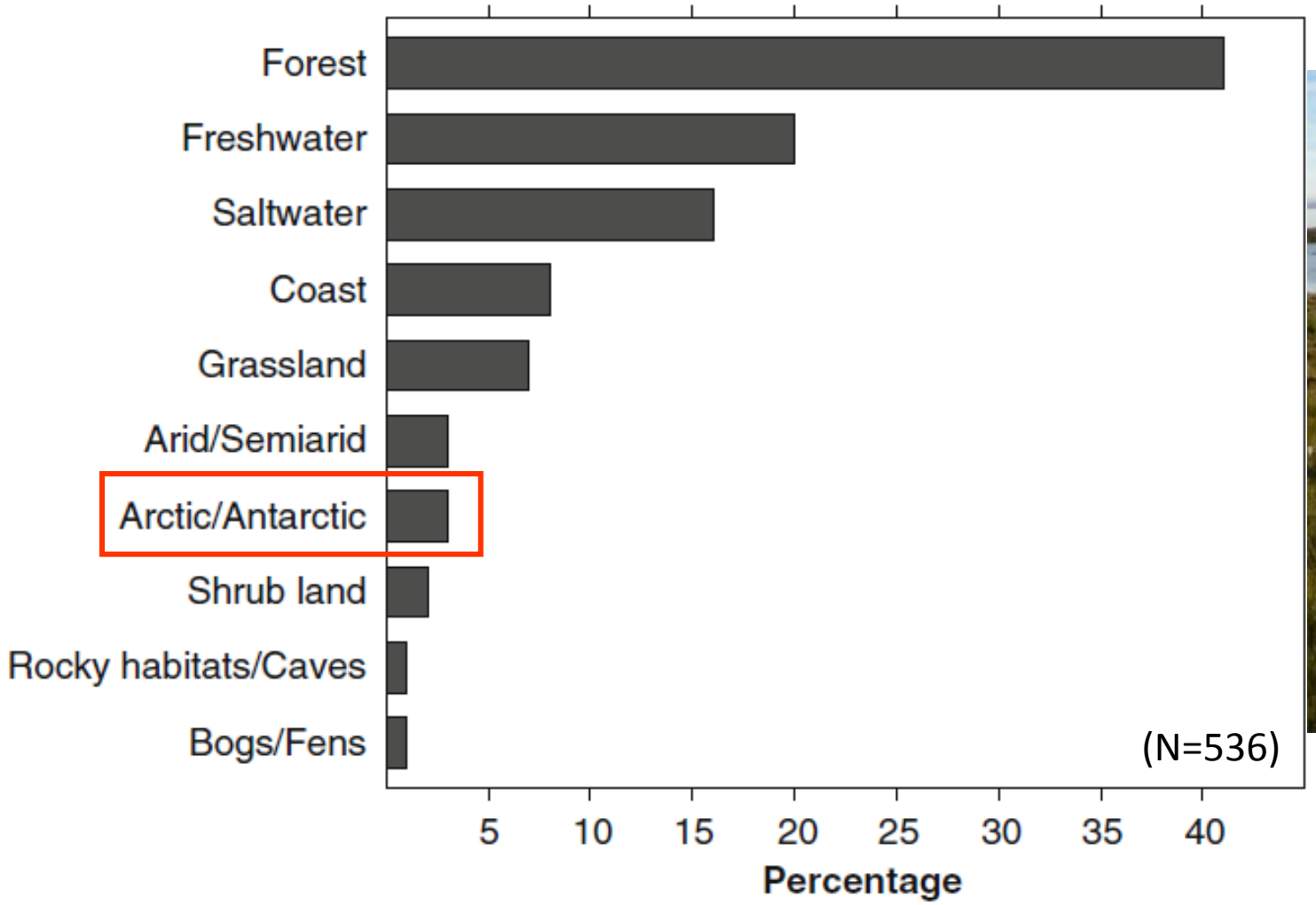


Jaeschke et al. (2014) ***Naturwissenschaften***

Climate Change Research



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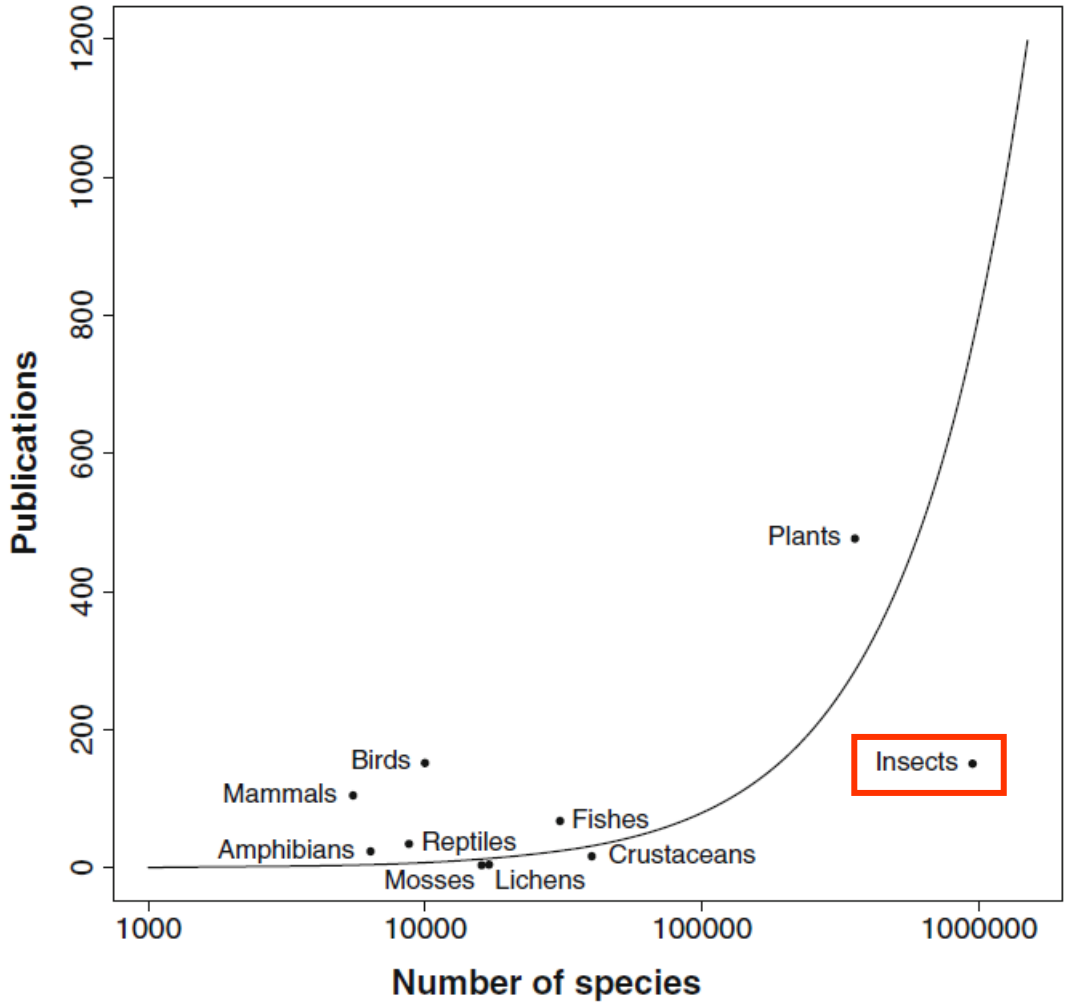

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Insects of the Arctic

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Phylum	Class	Order	Families	Genera	Species
Tardigrada (tardigrades)	Eutardigrada	Apochela	1	1	1
		Parachela	3	16	74
	Heterotardigrada	Arthrotardigrada	1	4	16
Bryozoa (moss animalcules)	Phylactolaemata	Parachela	1	1	1
Chelicerata (mites & spiders)	Arachnida	Acari:Acariformes	38	76	133
		Acari:Parasitiformes	10	14	27
		Araneae	4	14	21
Hexapoda (springtails & insects)	Collembola	Arthropleona	7	27	65
		Neelipleona	1	1	1
		Symphyleona	2	3	6
	Insecta	Phthiraptera (Anoplura+Mallophaga)	3	14	38
		Ephemeroptera	1	1	1
		Hemiptera (all aphids)	2	4	4
		Thysanoptera	1	1	1
		Mallophaga	2	12	36
		Coleoptera	12	18	21
		Diptera:Chironomidae	1	25	92
		Diptera:other	19	39	69
		Hymenoptera:Symphyta	1	4	10
		Hymenoptera:Parasitica	4	20	21
		Lepidoptera	6	12	12
		Siphonaptera	1	2	2
		Trichoptera	1	1	1
Crustacea (water fleas, ostracods and shrimps)	Branchiopoda	Cladocera	4	7	9
		Ctenopoda	1	1	1
		Notostraca	1	1	1
	Copepoda	Calanoida	2	2	2
		Cyclopoida	1	3	4
		Harpacticoida	3	3	3
		Siphonostomatoida	1	1	2
	Malacostraca	Amphipoda	1	1	2
		Mysidacea	1	1	1
	Ostracoda	Podocopida	4	8	10
Total				**556**	**1308**

Insecta: 308 species

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Arctic Biodiversity Assessment

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Order	Arctic Families	Arctic Genera	High Arctic Species	Low Arctic Species
Ephemeroptera	Metretopodidae	1	0	1
	Baetidae	1	0	7
	Heptageniidae	1	0	1
	Leptophlebiidae	1	0	1
	Ephemerellidae	1	0	1
Odonata	Aeshnidae	1	0	4
	Coenagriidae	1	0	1
	Corduliidae	1	0	1
Plecoptera	Pteronarcidae	1	0	1
	Chloroperlidae	3	0	3
	Perlodidae	5	0	5
	Perlidae	2	0	2
	Capniidae	1	0	6
	Nemouridae	3	0	5
Orthoptera	Acrididae	3	0	4
Phthiraptera	Philopteridae	21	23	37
	Trichodectidae	1	0	1
	Menoponidae	7	5	10
	Ricinidae	1	2	2
	Echinophthiriidae	2	2	2
	Linognathidae	1	0	1
	Pediculidae	1	0	1
	Hoplopleuridae	2	1	2
	Polyplacidae	1	0	2
Hemiptera	Lygaeidae	1	0	1
	Miridae	4	0	8
	Anthocoridae	1	0	1
	Saldidae	4	1	9
	Corixidae	2	0	3
	Cicadellidae	7	0	9
	Delphacidae	1	0	1
	Psyllidae	2	0	9
	Aphididae	17	3	20
	Coccidae	1	0	1
	Orthezidae	1	0	1
	Pseudococcidae	3	1	2

Order	Arctic Families	Arctic Genera	High Arctic Species	Low Arctic Species
Thysanoptera	not stated	3	1	2
Neuroptera	Chrysopidae	1	0	1
	Hemerobiidae	1	0	2
Coleoptera	Carabidae	16	1	85
	Haliplidae	1	1	2
	Dytiscidae	7	2	24
	Hydrophilidae	2	0	6
	Silphidae	3	0	3
	Staphylinidae	17	4	23
	Byrrhidae	3	0	5
	Bupestridae	1	0	1
	Elateridae	2	0	7
	Cantharidae	2	0	2
	Dermestidae	1	0	1
	Cucujidae	1	0	1
	Coccinellidae	5	0	6
	Lathridiidae	2	1	2
	Cerambycidae	5	0	5
	Chrysomelidae	6	0	13
	Curculionidae	9	1	14
Diptera	Trichoceridae	1	2	5
	Tipulidae	13	9	52
	Dixidae	1	0	1
	Chaoboridae	2	0	2
	Culicidae	2	3	17
	Simuliidae	6	0	28
	Ceratopogonidae	4	3	4
	Chironomidae	62	93	159
	Bibionidae	1	0	1
	Scatopsidae	2	0	3
	Mycetophilidae	9	9	17
	Sciaridae	4	5	3
	Cecidomyiidae	2	2	2
	Rhagionidae	2	0	2
	Tabanidae	1	0	4
	Empididae	4	7	20
	Dolichopodidae	7	2	31

Culicidae: 20 species

Hodkinson et al. (2013)
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Culicidae: 20 species

Hodkinson et al. (2013)
Arctic Biodiversity Assessment

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Mosquito-borne Viruses

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	Jamestown Canyon	Snowshoe hare	Northway
Bison bison Bison	89%	89%	94%
Ovis dalli Dall sheep	51%	41%	84%
Lepus Americans Snowshoe hare	43%	65%	3%
Alopex lagopus Arctic fox	3%	NA	NA
Rangifer tarandus Caribou	NA	NA	43%

Bradley et al. (2005) Int J Circumpolar Health

Vectors of the Arctic

Canadian Arctic:

Aedes canadiensis
Aedes vexans
Culex pipiens
Culex restuans

→ West Nile Virus

Aedes communis
Aedes hexodontus
Aedes punctor

→ Snowshoe Hare Virus

Aedes hexodontus

→ Northway Virus

CDC Arctic Investigations Program (2004)
Mc Lean 1977 Journal of Hygiene

Vectors of the Arctic

Canadian Arctic:

Aedes *canadiensis*
Aedes *vexans*
Culex pipiens
Culex restuans

→ West Nile Virus

Aedes *communis*
Aedes *hexodontus*
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→ Snowshoe Hare Virus

Aedes *hexodontus*

→ Northway Virus

1. Mosquitoes and the Arctic
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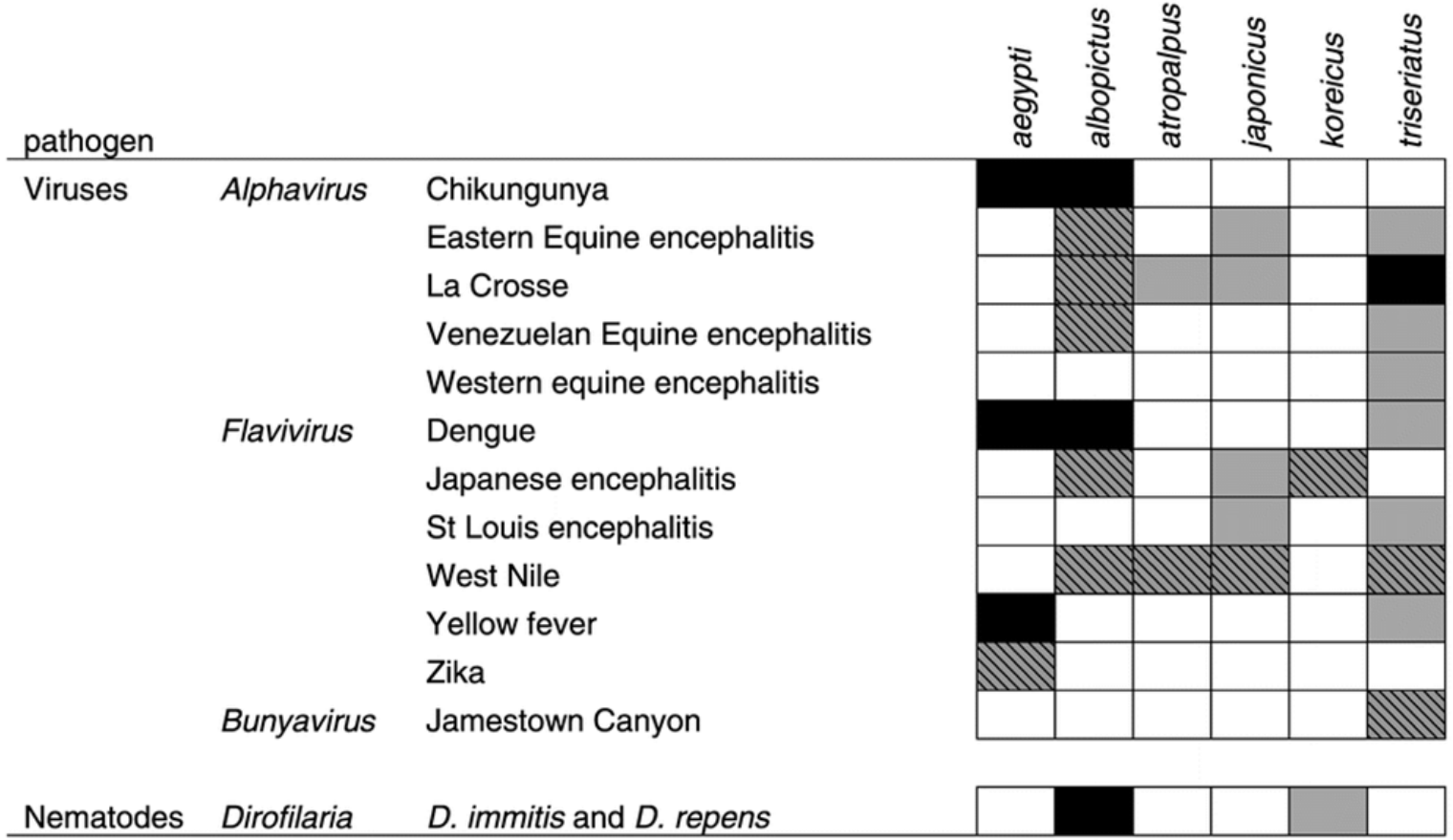
Invasive Aedine Vectors



Medlock et al. (2012) Vector Borne Zoonotic Dis

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Invasive Aedine Vectors

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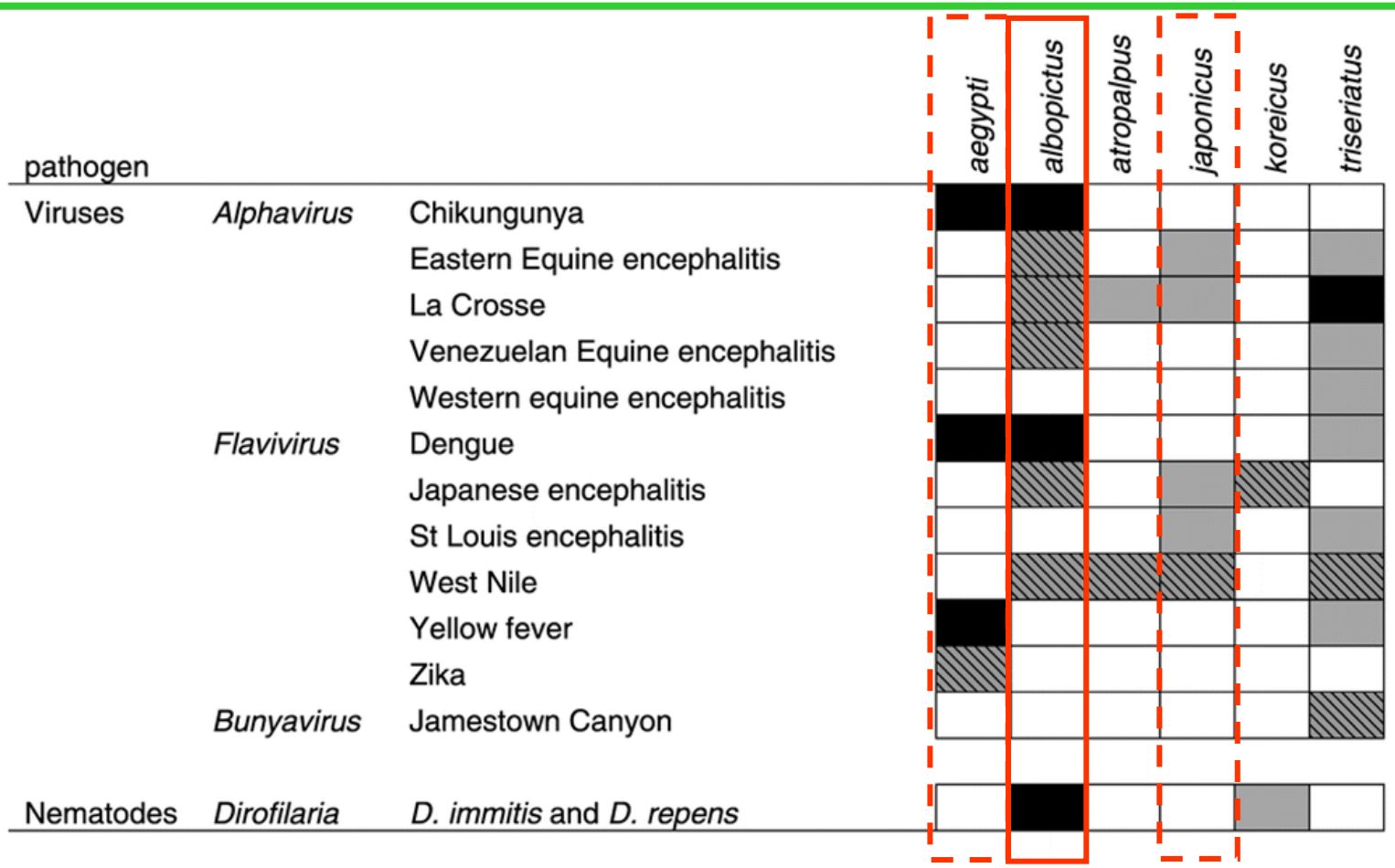

Medlock et al. (2012) Vector Borne Zoonotic Dis

Aedes albopictus

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Aedes albopictus

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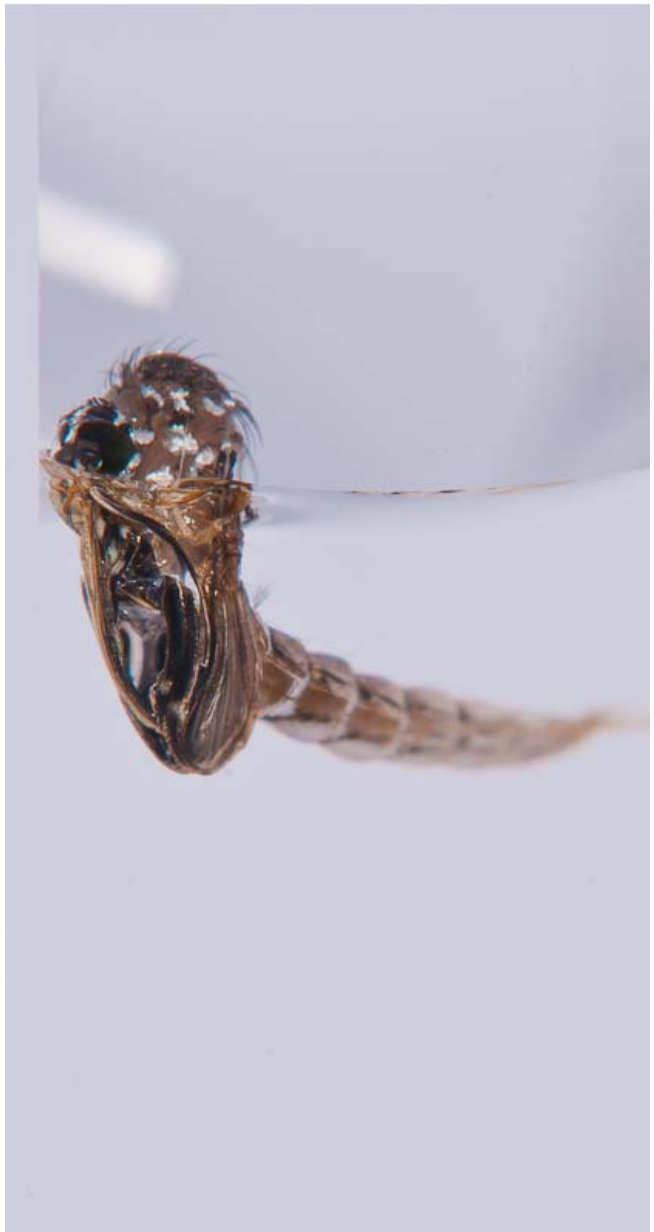

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Aedes albopictus

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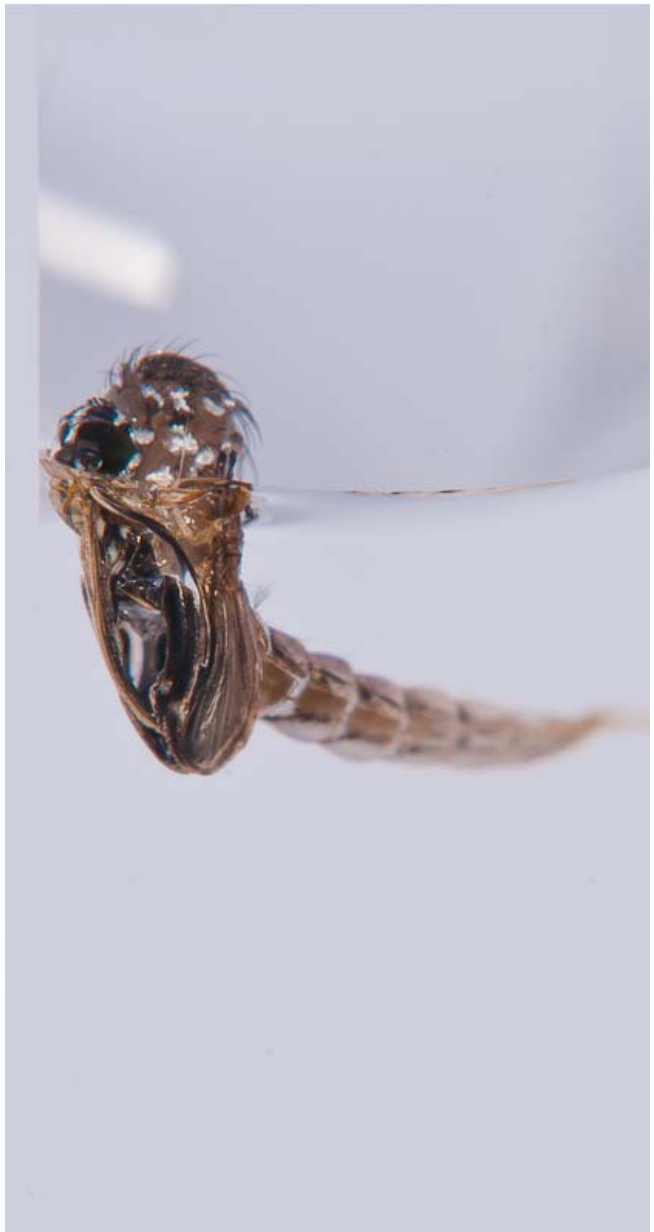

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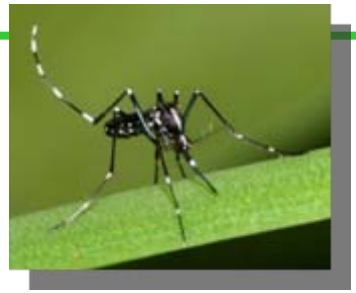

The „Asian Tiger Mosquito“ (*Aedes albopictus*)

- Dispersed on all continents except the Arctic mainly due to the shipping of used tires and potted plants („lucky bamboo“)

- Establishment started in harbours and ports, where the traded goods were landed

- Aggressive day-biter and treehole breeder

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Aedes albopictus

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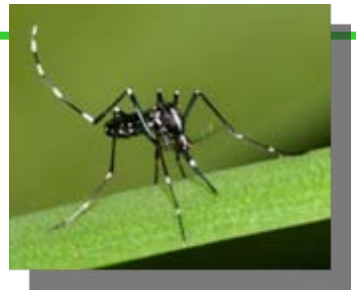

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Historical Spread

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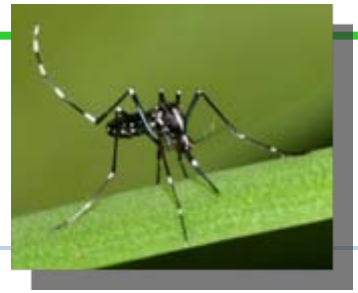
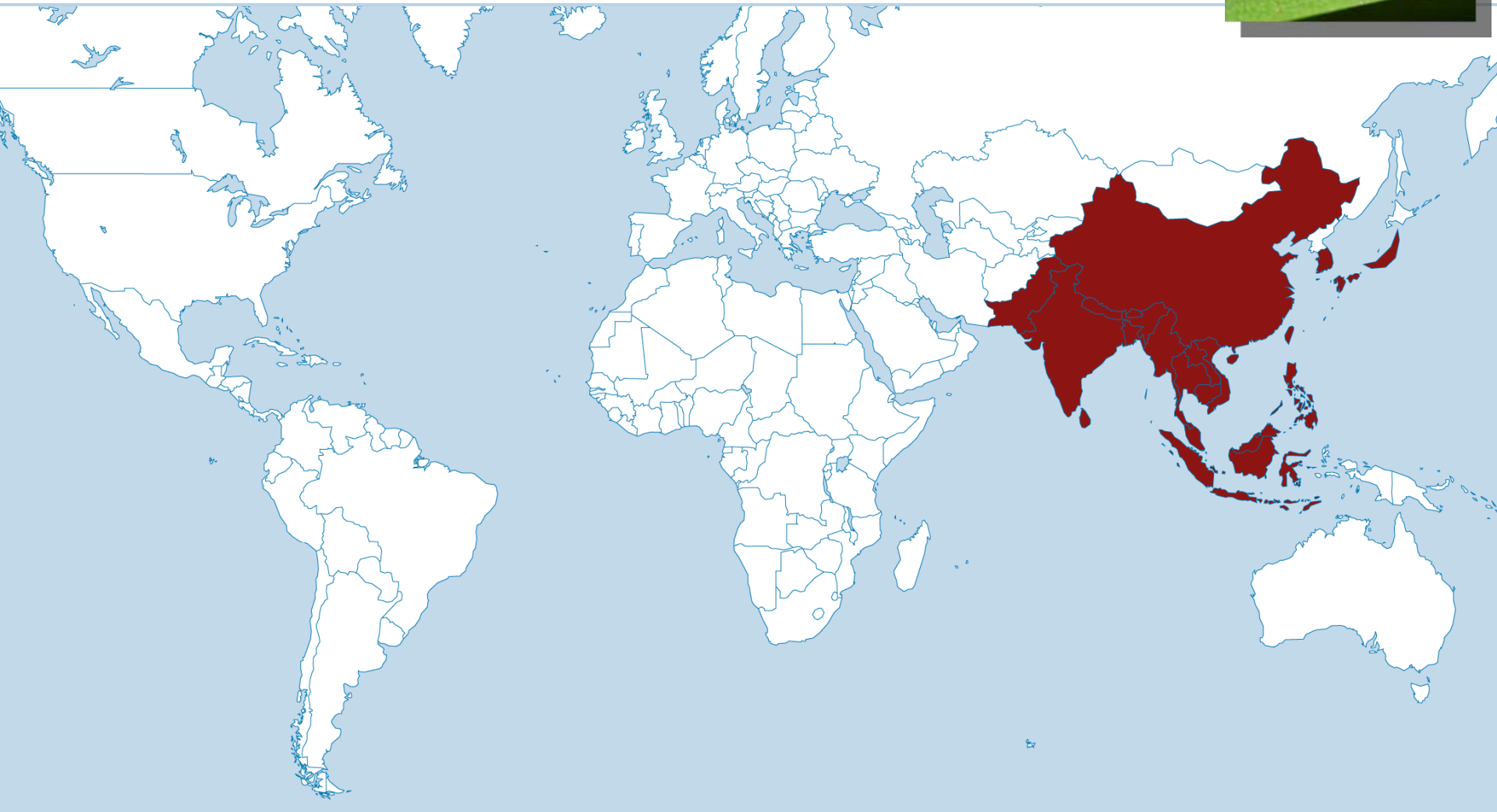


Until 1978



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Historical Spread

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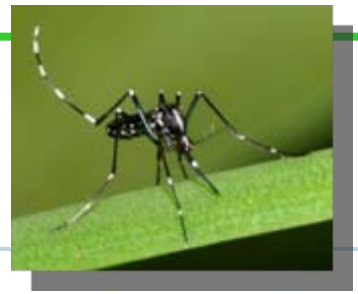
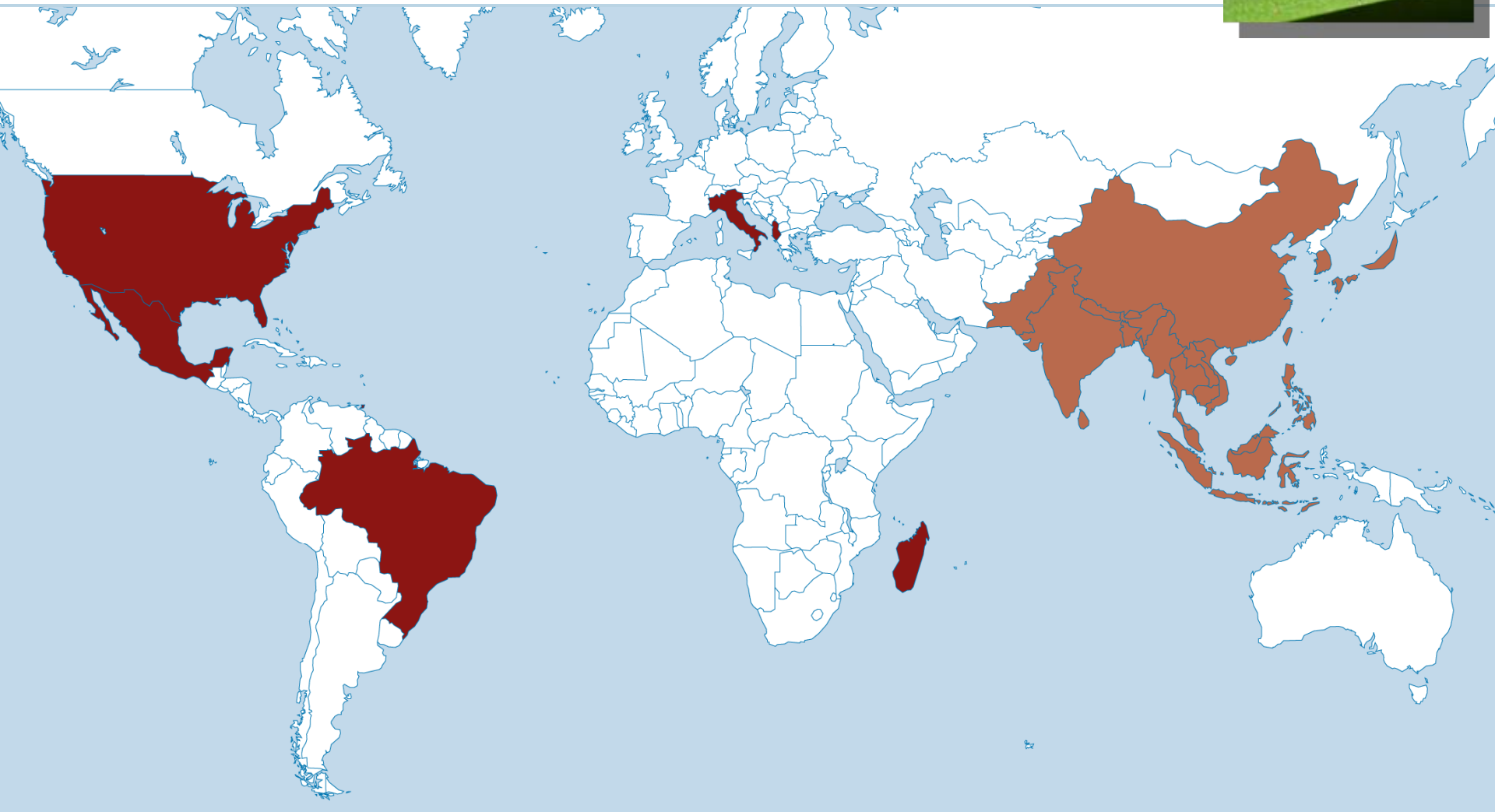


Until 1990



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Historical Spread

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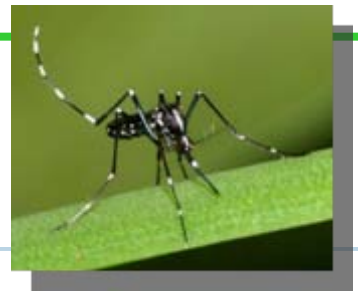

Until 2000

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Historical Spread

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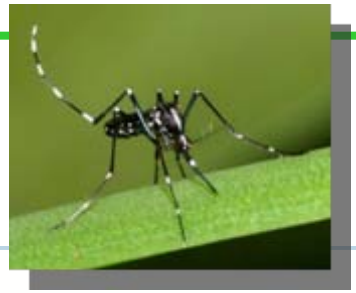

Until today

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Historical Spread

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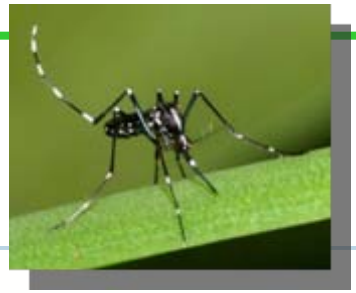

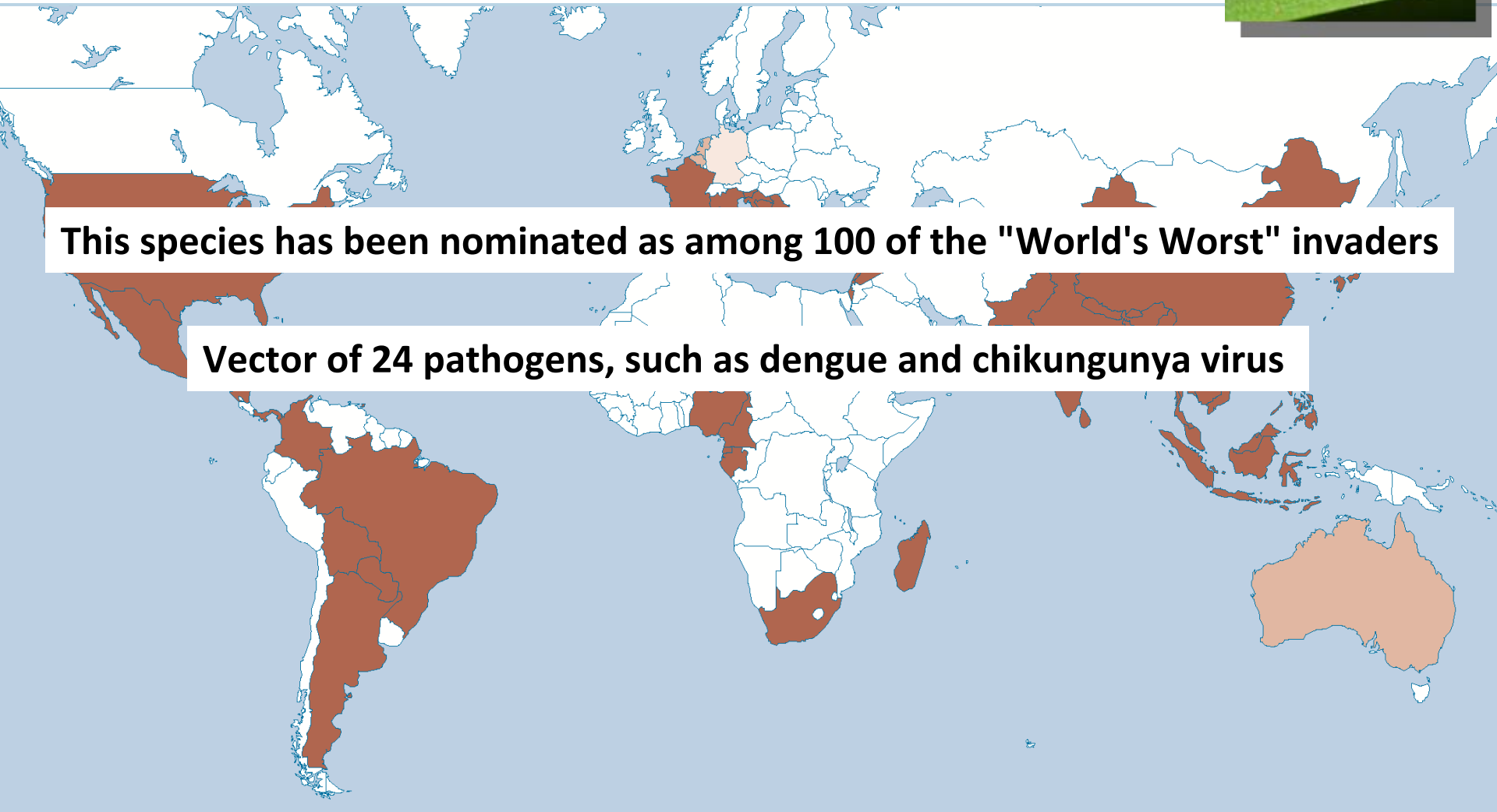

This species has been nominated as among 100 of the "World's Worst" invaders

Vector of 24 pathogens, such as dengue and chikungunya virus

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Bioclimatic Models

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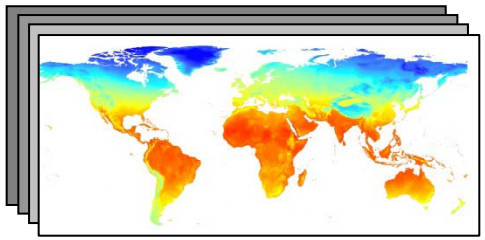
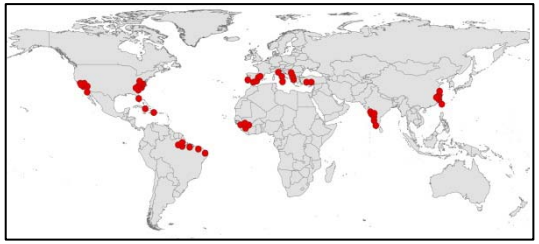
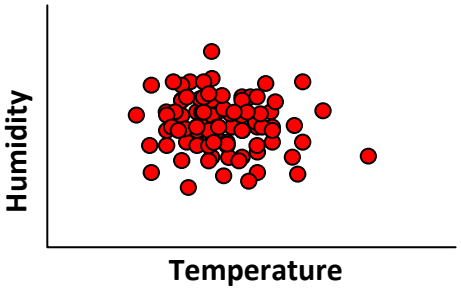
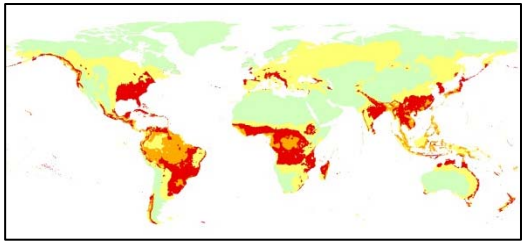
1.) Connect climatic variables / presence records



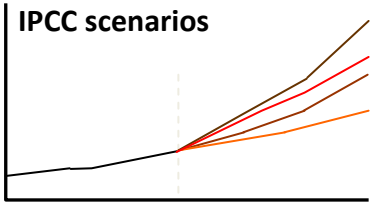


2.) Identify bioclimatic envelopes

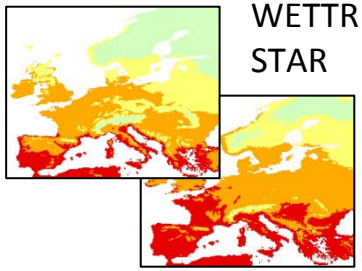




3.) Relate to climate change models



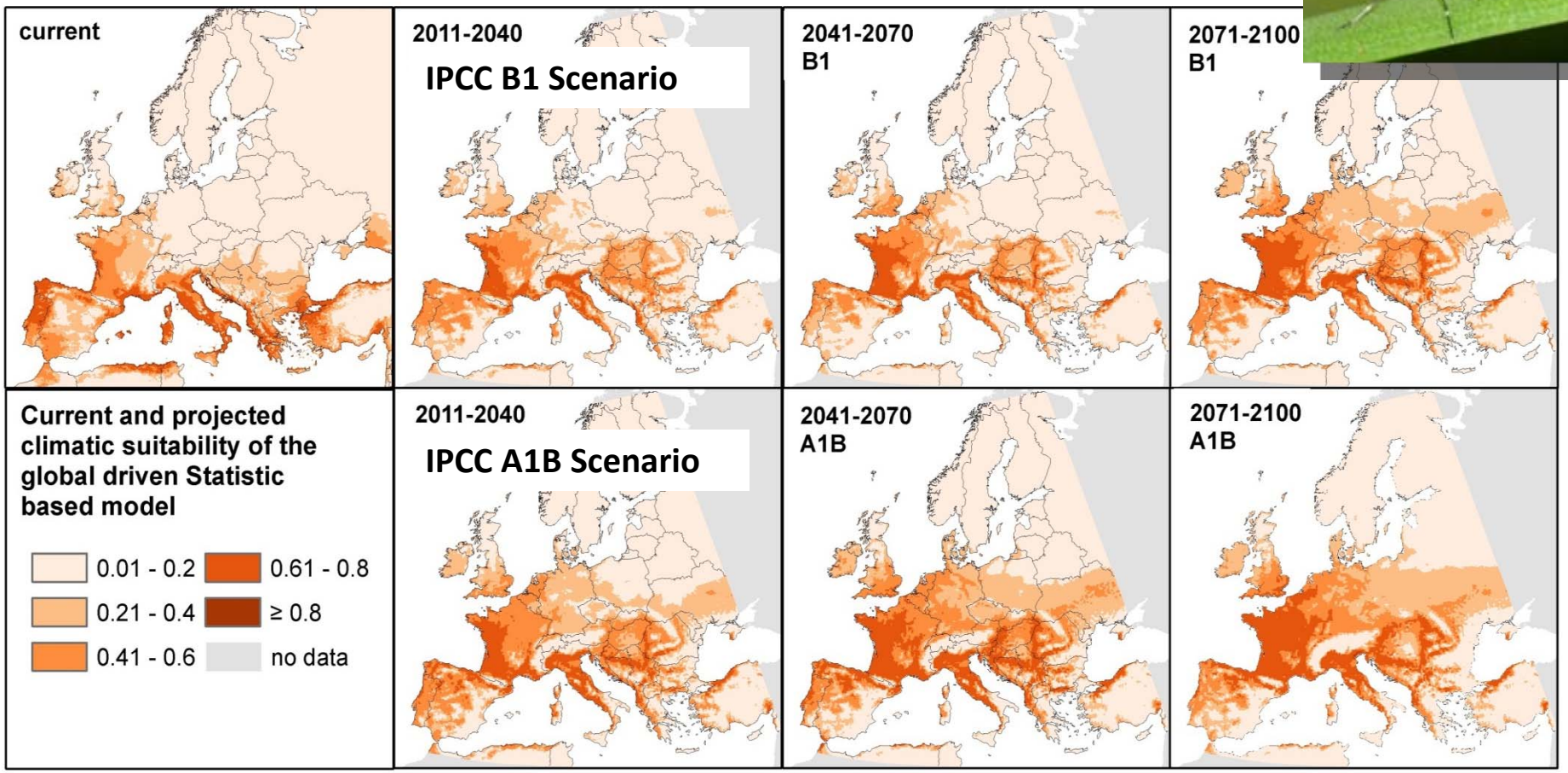
COSMO CLM
REMO
WETTREG
STAR



Fischer, Thomas, Beierkuhnlein (2010) ***Nova Acta Leopoldina***

Bioclimatic Models

Aedes albopictus – Geostatistical Model



Fischer, Thomas et al. (2011) ***Global Planetary Change***

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Bioclimatic Models

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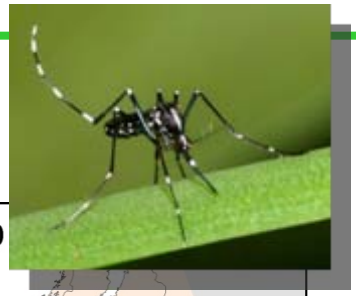
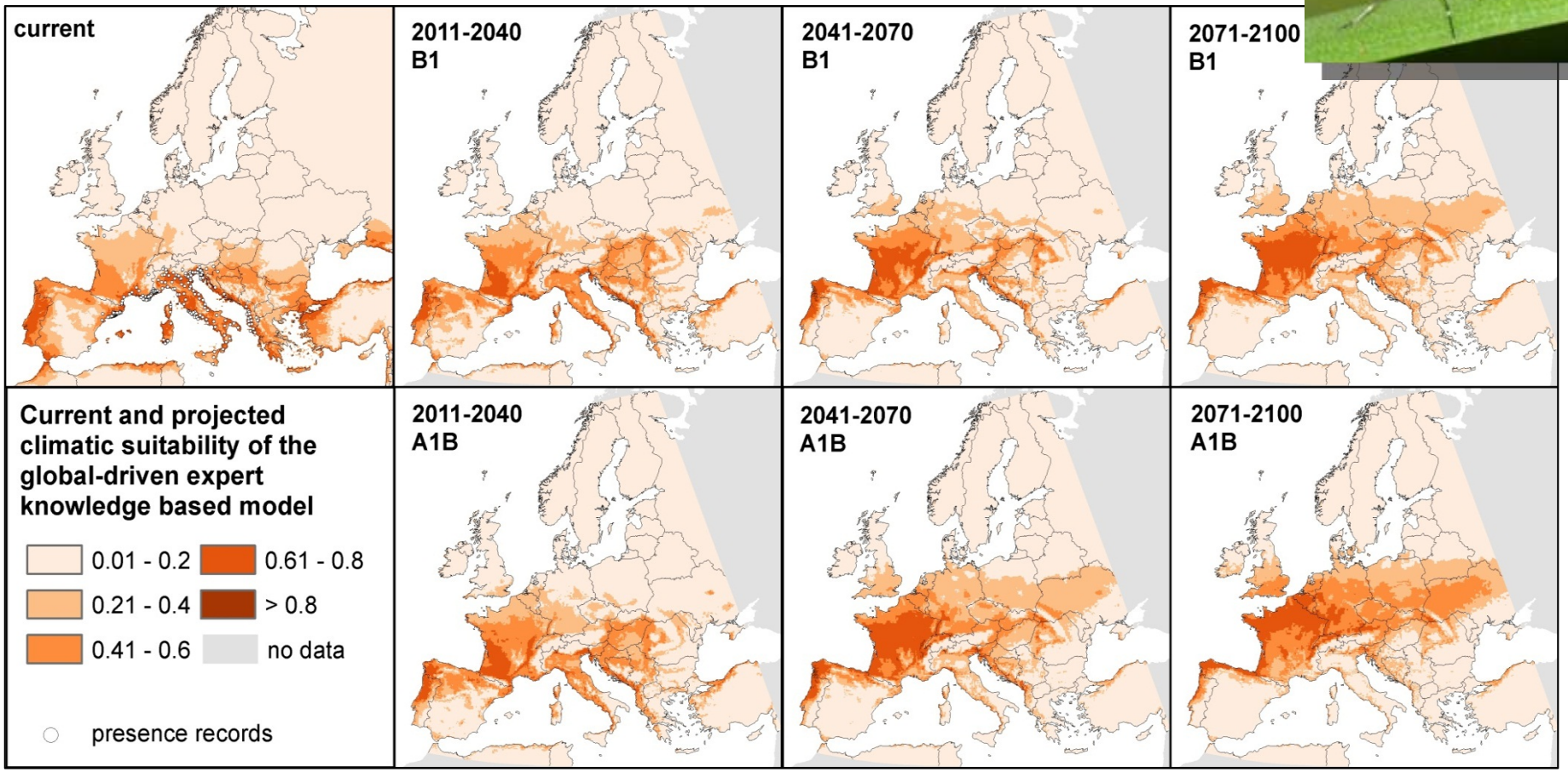


Aedes albopictus – Expert based Modell



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Different Models

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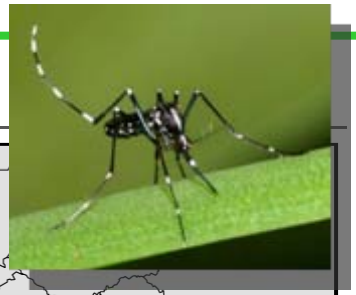

Expected tendencies in climatic conditions for *Aedes albopictus* up to the mid-century

- Persistently suitable
- Increasingly suitable
- Persistently unsuitable
- Increasingly unsuitable
- Persistently unsuitable to increasingly suitable
- Persistently suitable to increasingly unsuitable
- Increasingly suitable to increasingly unsuitable
- Documented establishments of *Aedes albopictus*

Fischer & Thomas et la. (2014) ***Eurosurveillance***

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Different Models

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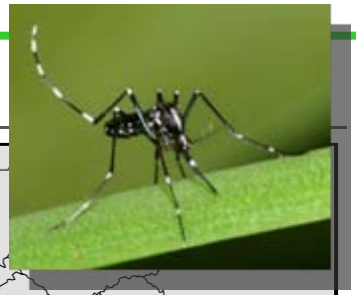

Aim: Involve vector ecology to do a better job

Expected tendencies in climatic conditions for *Aedes albopictus* up to the mid-century

- Persistently suitable
- Increasingly suitable
- Persistently unsuitable
- Increasingly unsuitable
- Persistently unsuitable to increasingly suitable
- Persistently suitable to increasingly unsuitable
- Increasingly suitable to increasingly unsuitable
- Documented establishments of *Aedes albopictus*

Fischer & Thomas et la. (2014) ***Eurosurveillance***

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Regional Adaptation

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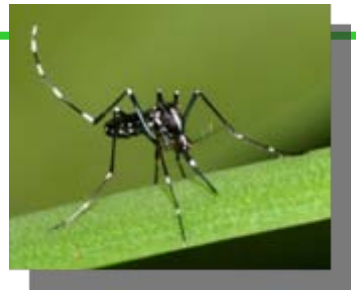
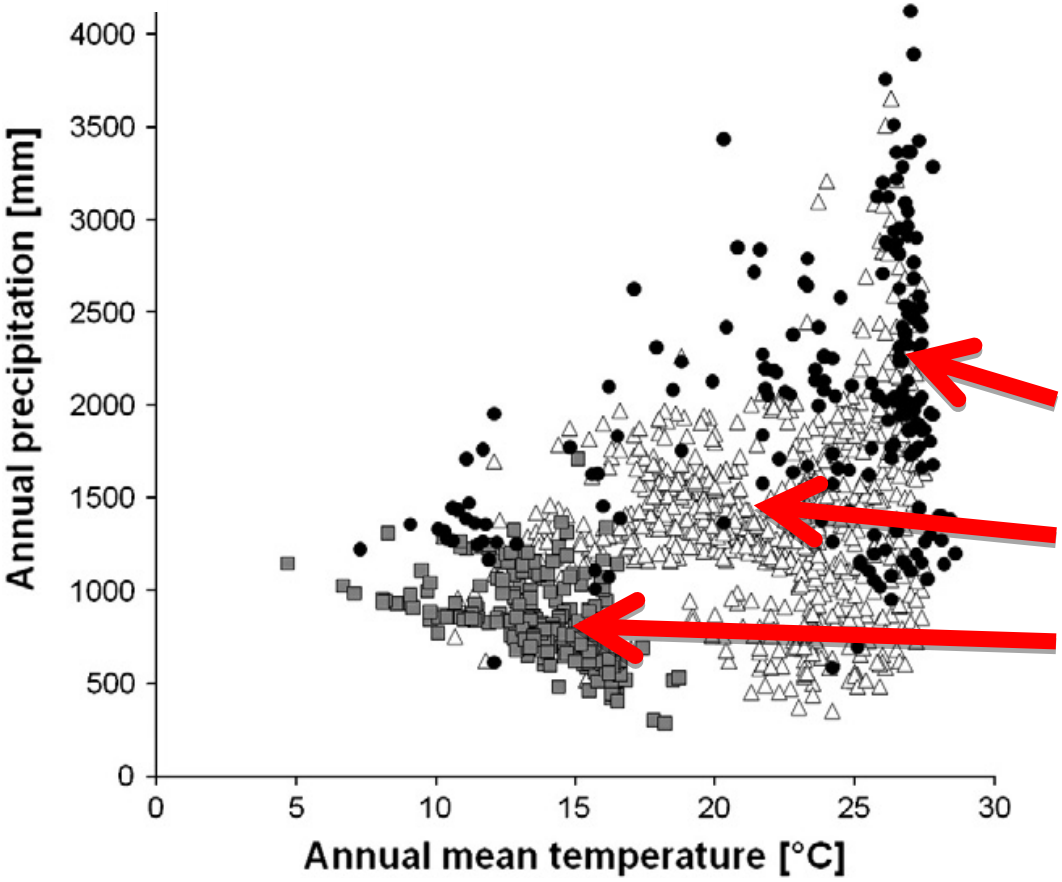


Differences in climatic conditions between the native and the invaded range of *Aedes albopictus*



Native populations (SE Asia)

Invasive except Europe

Europe

Fischer & Thomas et al. (2011) ***Global Planetary Change***

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Cold Tolerance

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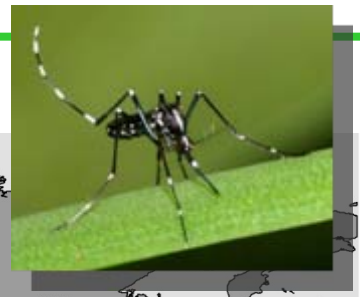
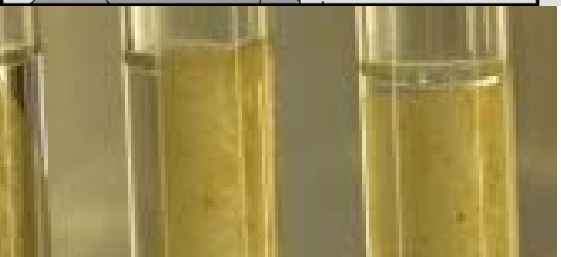
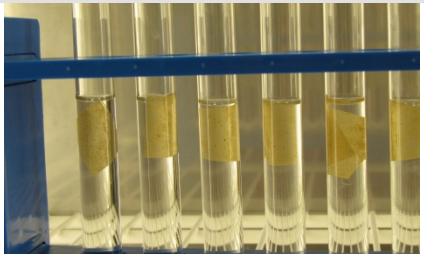


Coldest regions with *Aedes albopictus*

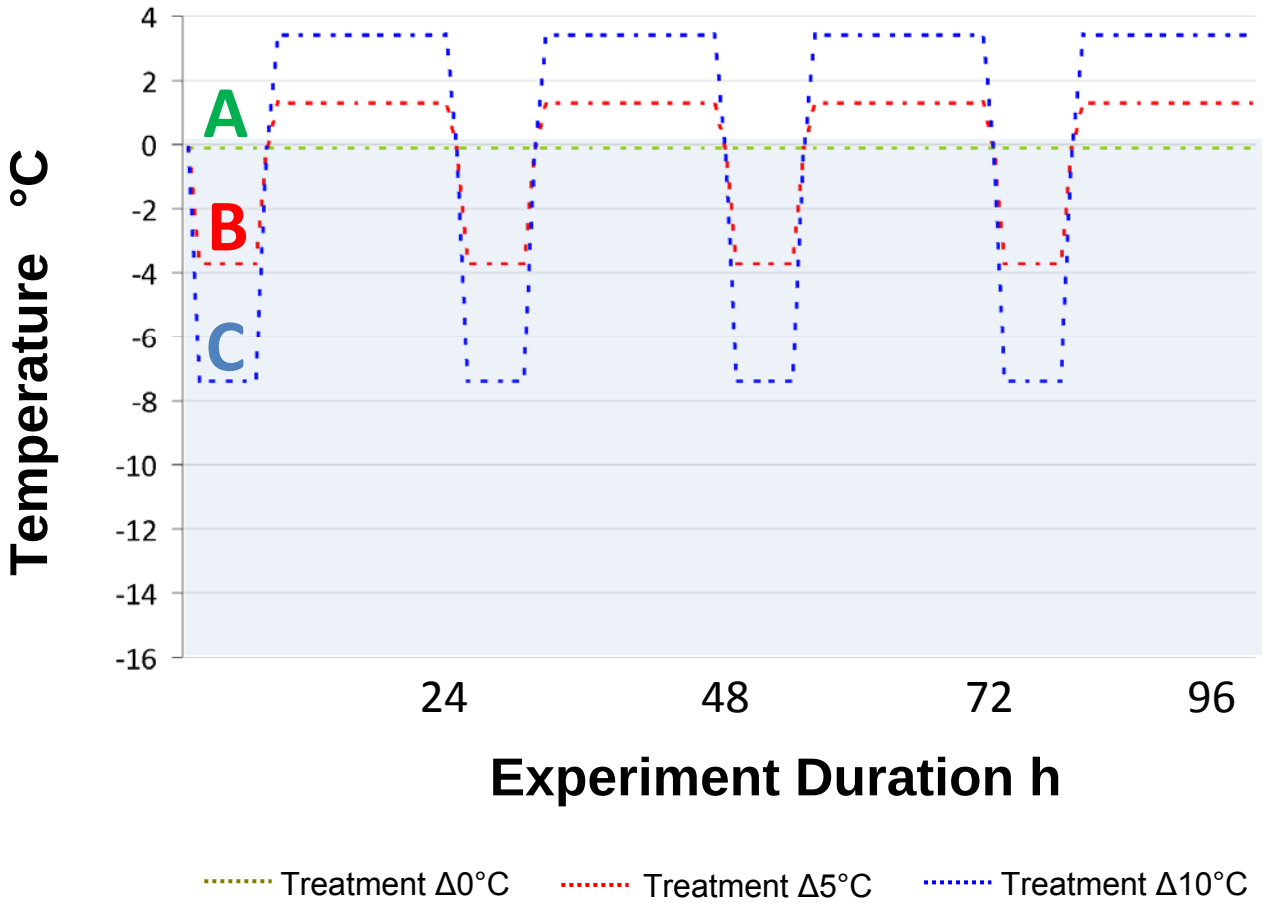




1. Mosquitoes and the Arctic
2. Invasive mosquito vectors
3. Modelling areas at risk in the light of Climate Change
4. **Low temperature survival of mosquito eggs**
5. Conclusion

Cold Tolerance

Does the range of diurnal temperature modifies the cold tolerance of *Aedes* eggs?



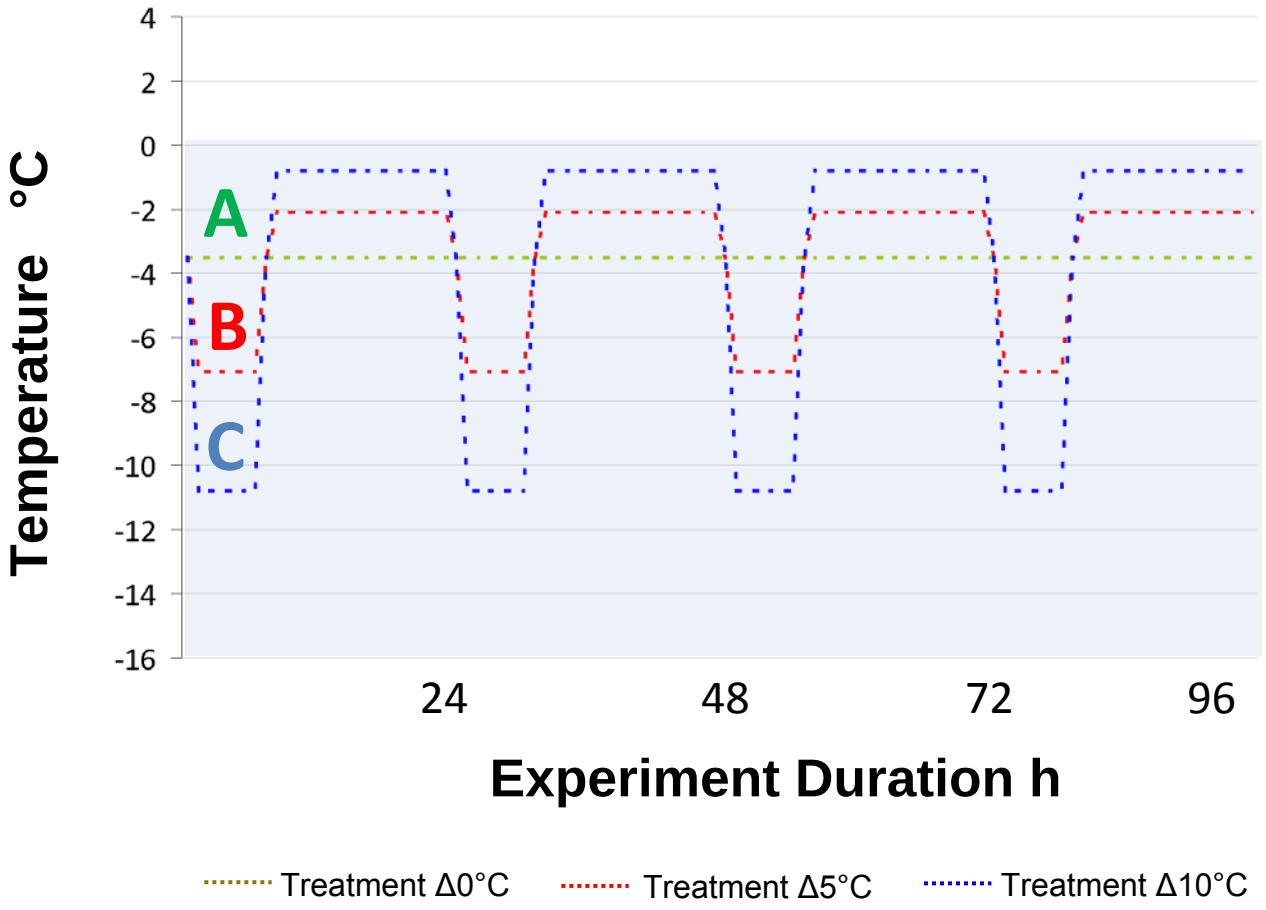
T_{mean} -0,1°C

Frost

Thomas et al. in prep

Cold Tolerance

Does the range of diurnal temperature modify the cold tolerance of *Aedes* eggs?



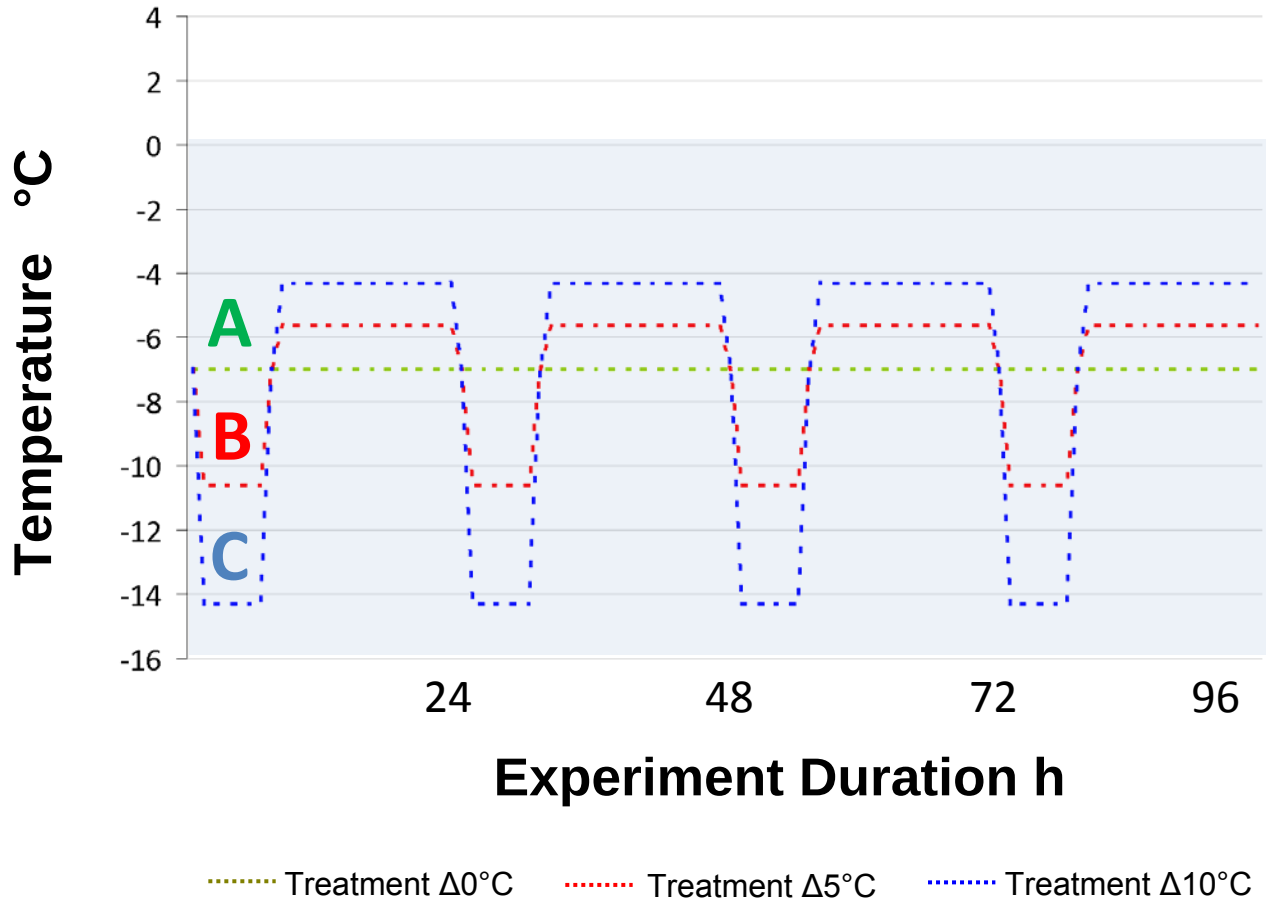
T_{mean} -3,5°C

Frost

Thomas et al. in prep

Cold Tolerance

Does the range of diurnal temperature modify the cold tolerance of *Aedes* eggs?



T_{mean} -7,0°C

Frost

Thomas et al. in prep

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Cold Tolerance

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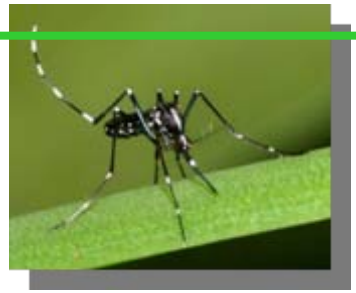
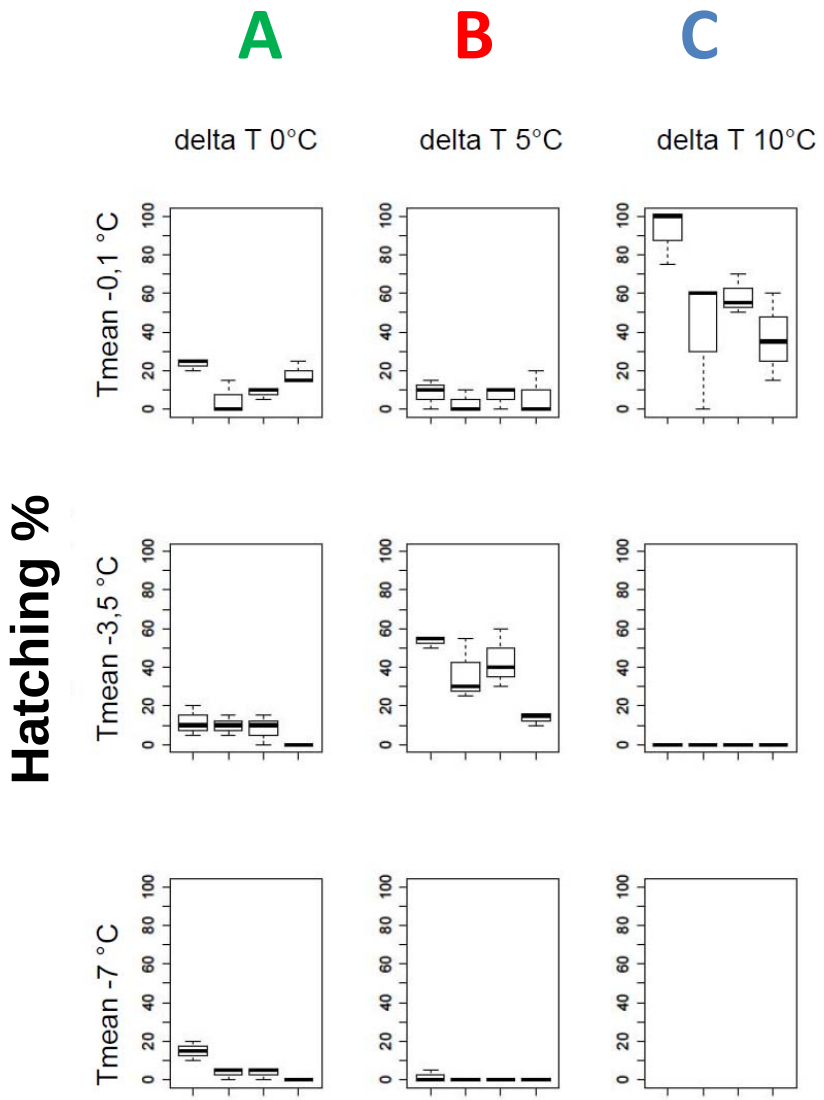


Aedes albopictus



Thomas et al. in prep

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Cold Tolerance

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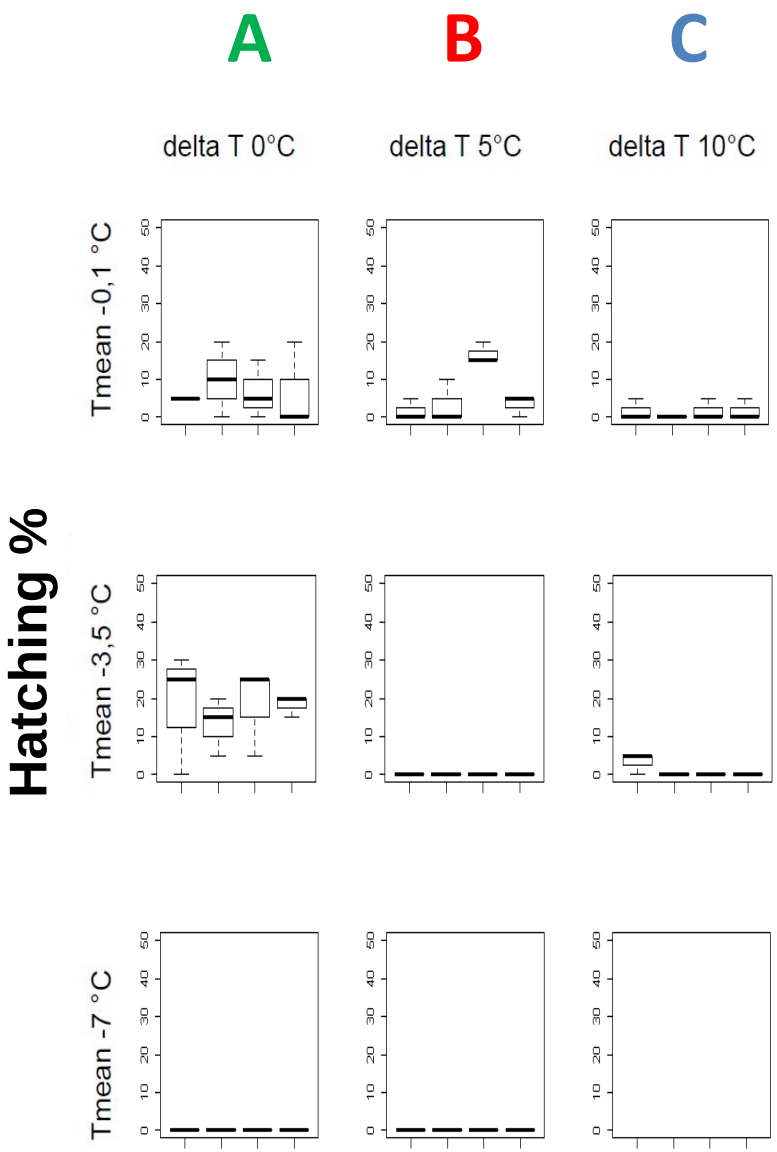

Aedes japonicus

Thomas et al. in prep

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BRTs *Aedes albobictus*

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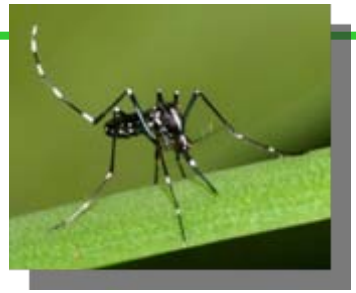
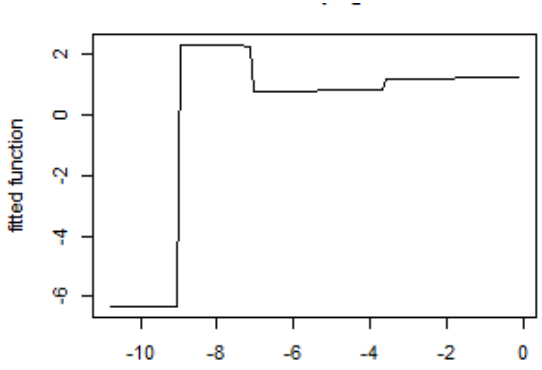
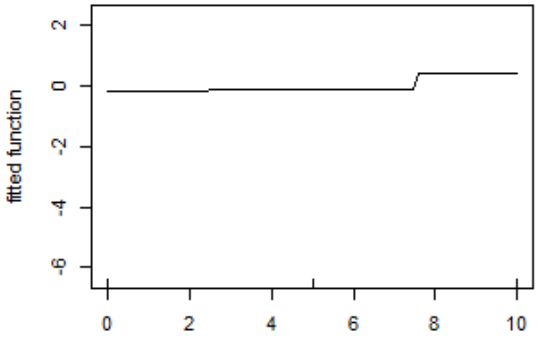
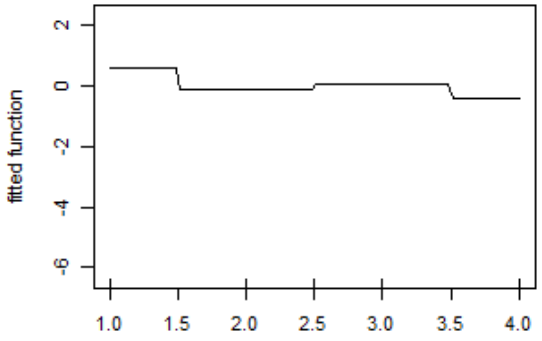




Tmin 61%



Delta 20%



Day 19%

Thomas et al. in prep

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BRTs *Aedes albobictus*

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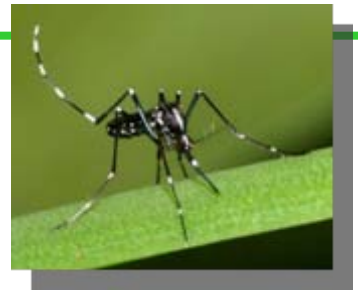
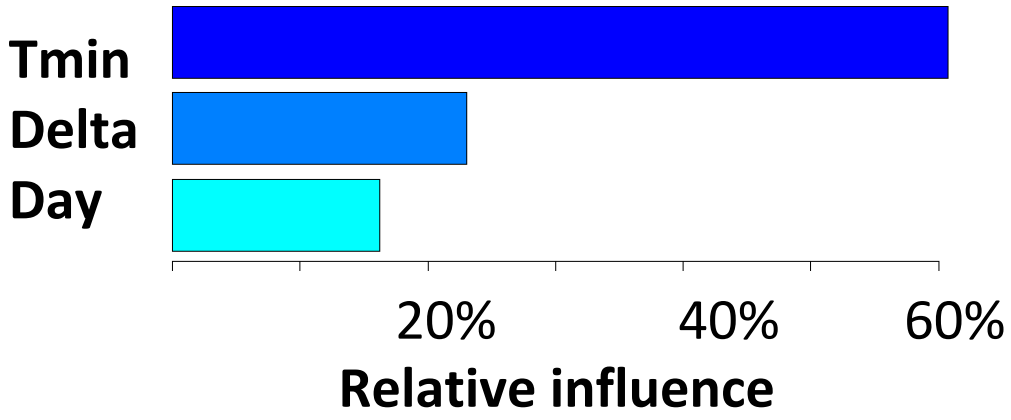
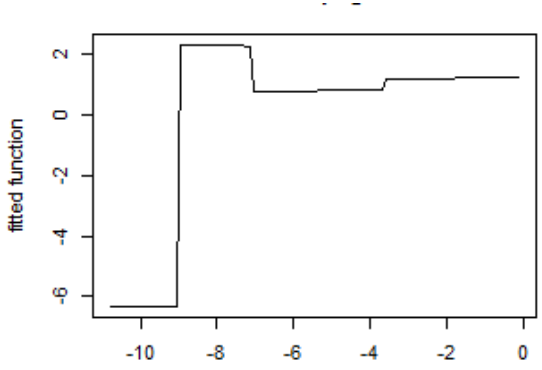
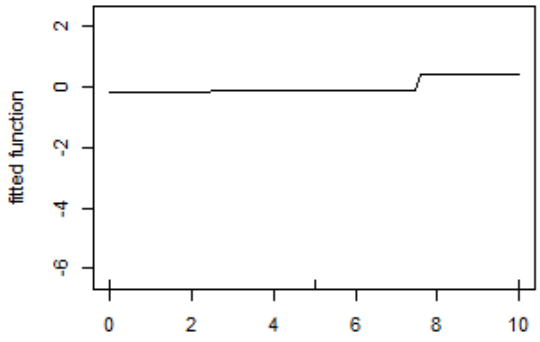




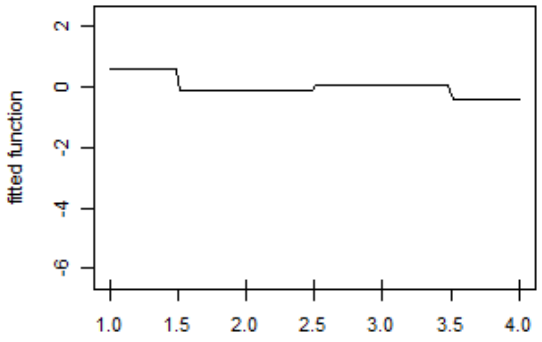
explained variance:
cv correlation = 0.89



Tmin 61%



Delta 20%



Day 19%

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BRTs *Aedes japonicus*

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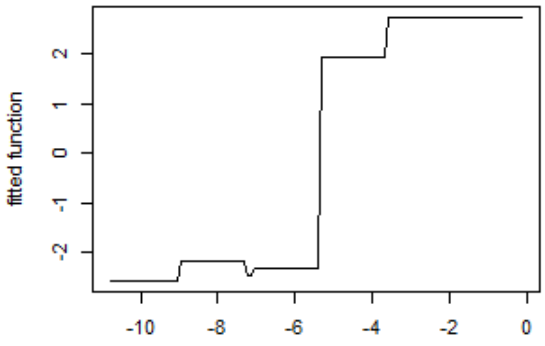
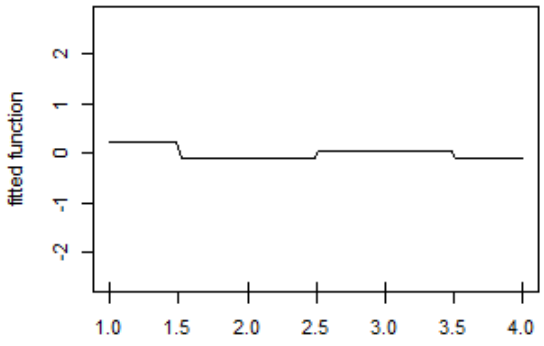
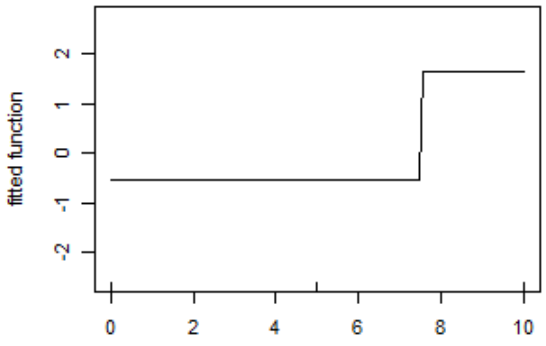


Tmin 96%



Delta 3%



Day 1%

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BRTs *Aedes japonicus*

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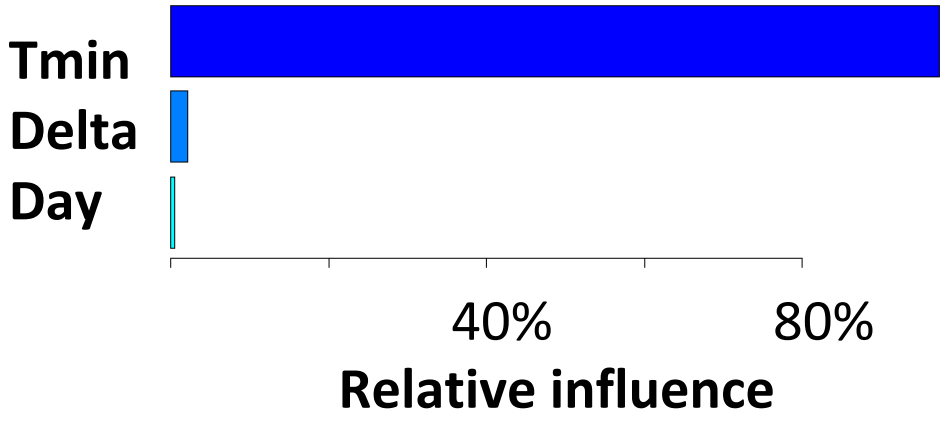
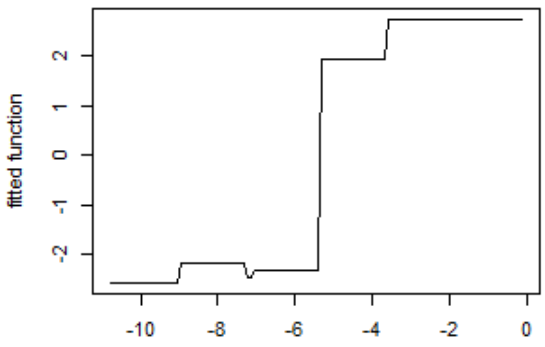
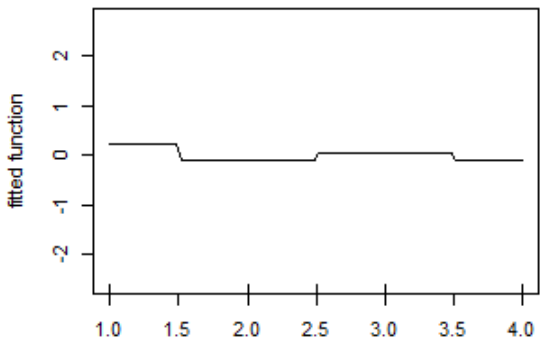


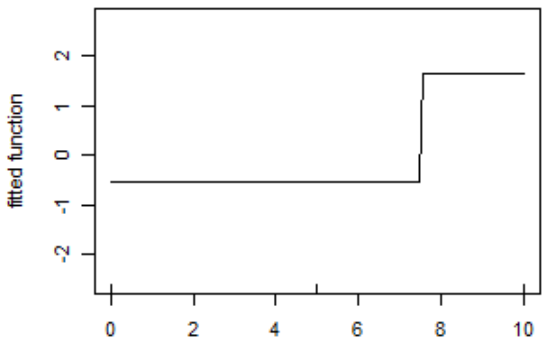
explained variance:
cv correlation = 0.62



Tmin 96%



Delta 3%



Day 1%

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Comparison: Tmin!

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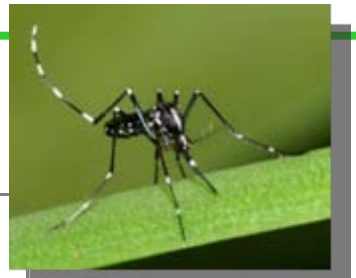

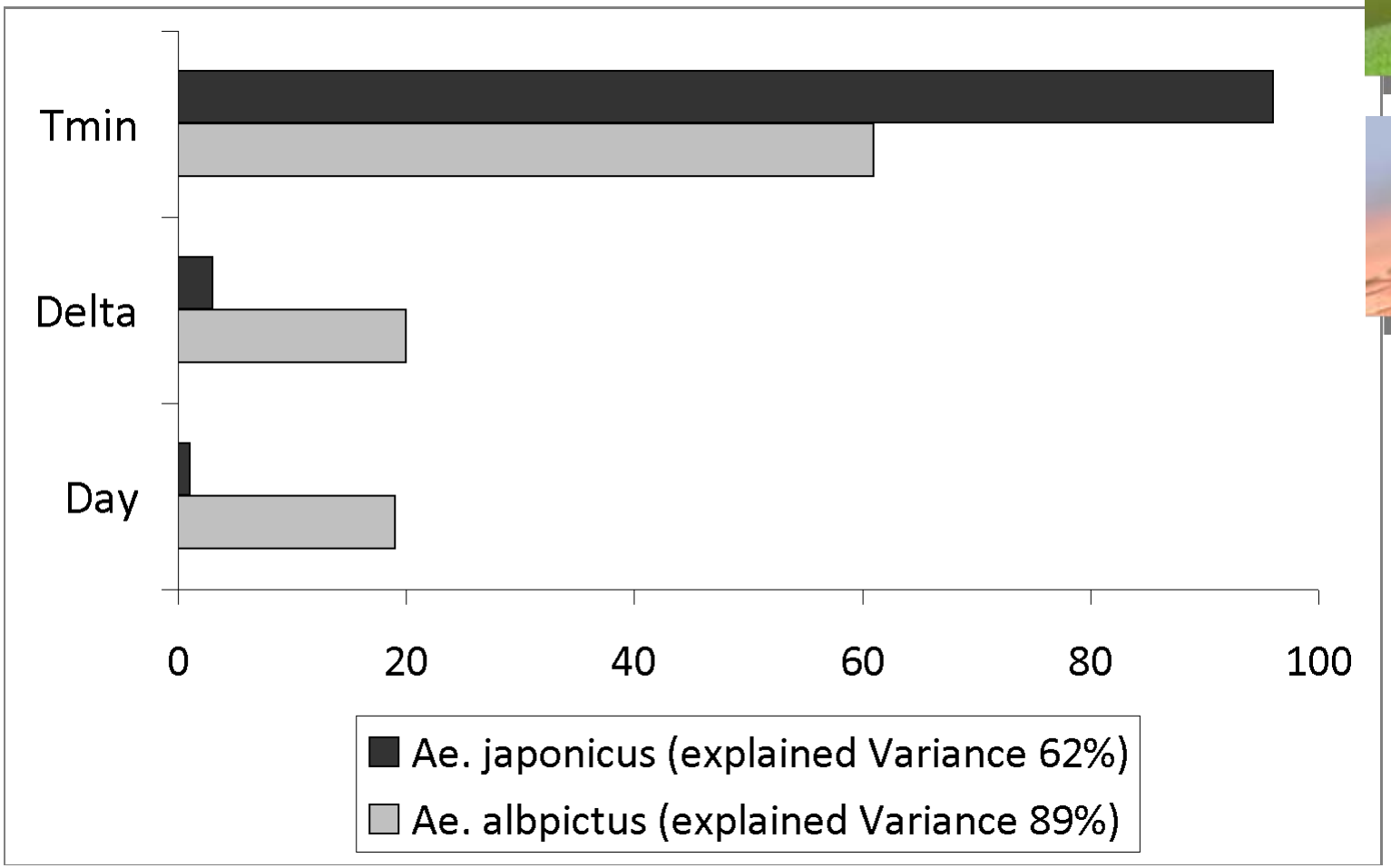

Thomas et al. in prep

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Low Temperature Survival

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What is the cold tolerance of *Aedes albopictus* eggs?

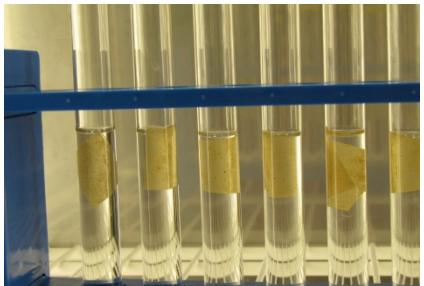
Thomas *et al. Parasites & Vectors* 2012, **5**:100
http://www.parasitesandvectors.com/content/5/1/100

Parasites & Vectors

RESEARCH **Open Access**

Low-temperature threshold for egg survival of a post-diapause and non-diapause European aedine strain, *Aedes albopictus* (Diptera: Culicidae)

Stephanie Margarete Thomas[1*], Ulla Obermayr[2], Dominik Fischer[1], Juergen Kreyling[1] and Carl Beierkuhnlein[1]



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Experimental Design

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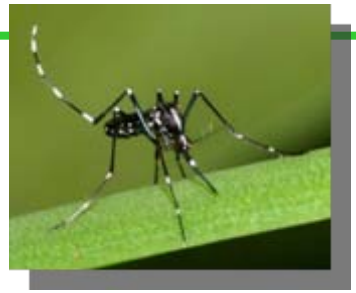


Strains

Aedes albopictus North Italy, artificial diapause

Aedes albopictus North Italy, non-diapausing

Aedes albopictus Singapore, non-diapausing

Aedes aegypti, non-diapausing

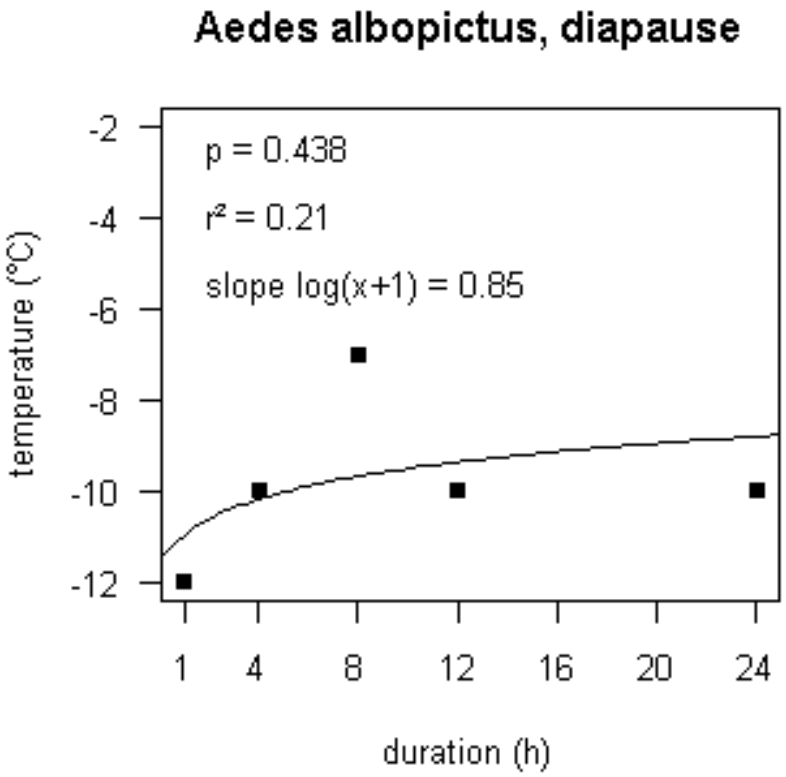
Temperatures

0°C	-2°C	-5°C	-7°C	-10°C	-12°C	-15°C

Durations

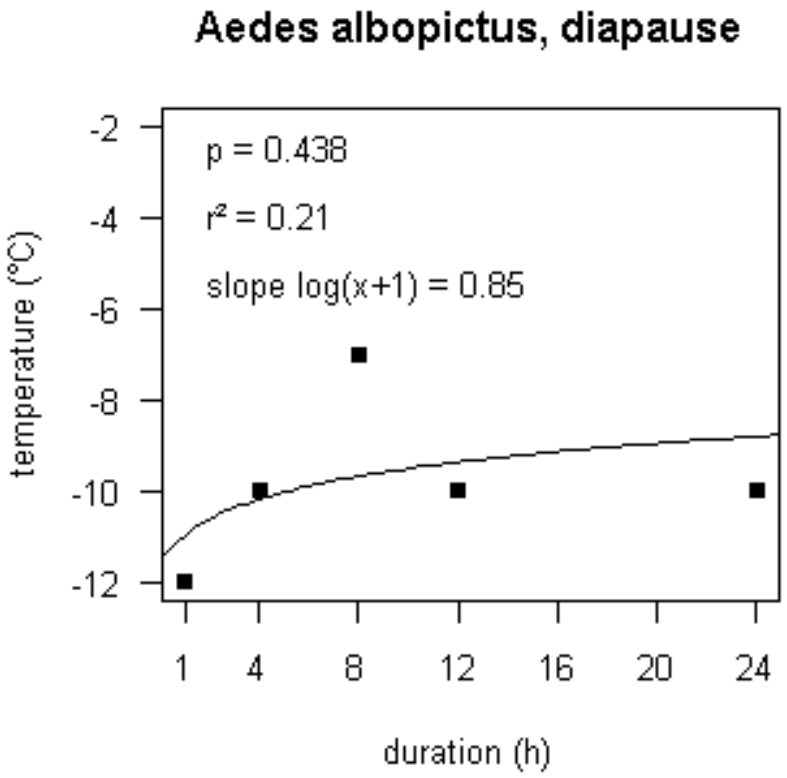
1 hour	4 hours	8 hours	12 hours	24 hours

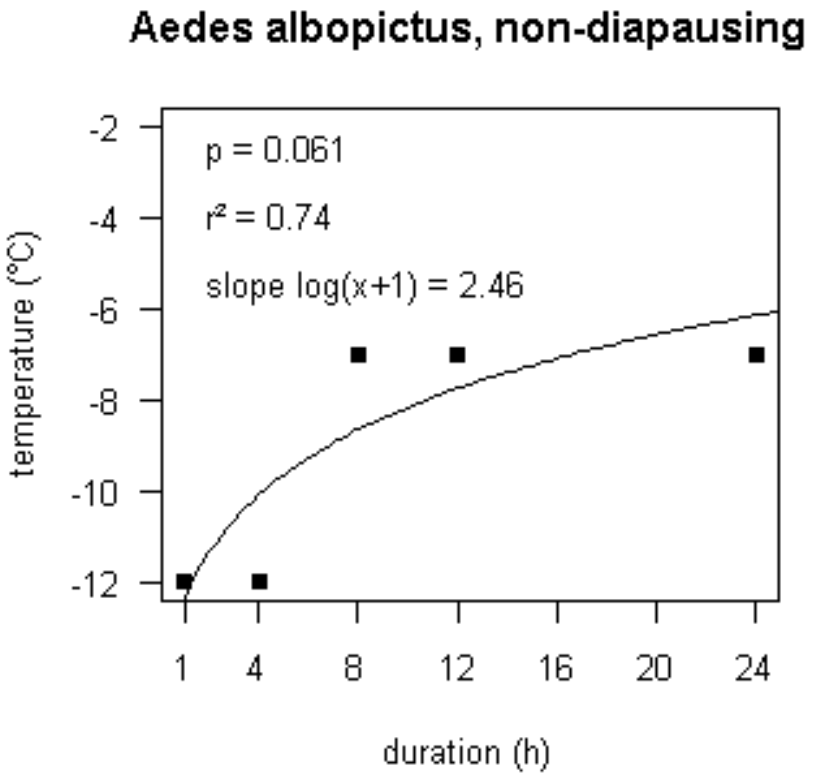
Low Temperature Survival



Thomas et al. (2012) ***Parasites & Vectors***

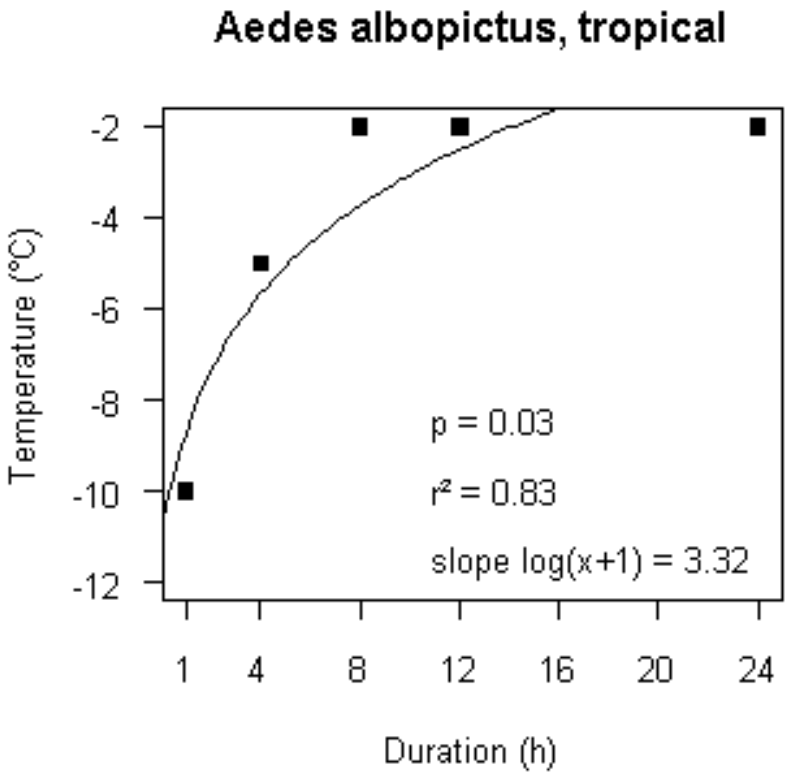
Low Temperature Survival





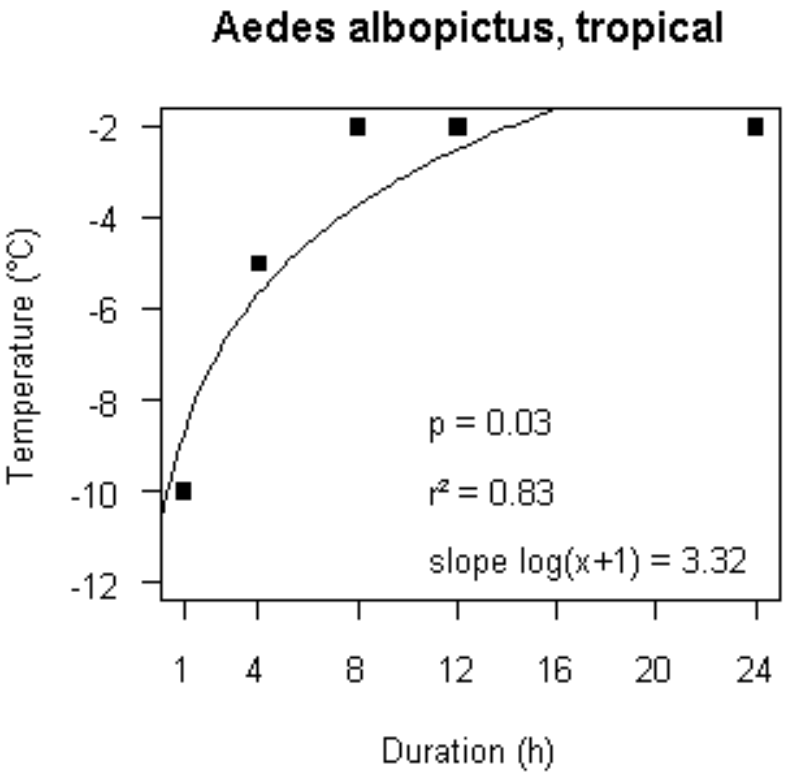
Thomas et al. (2012) ***Parasites & Vectors***

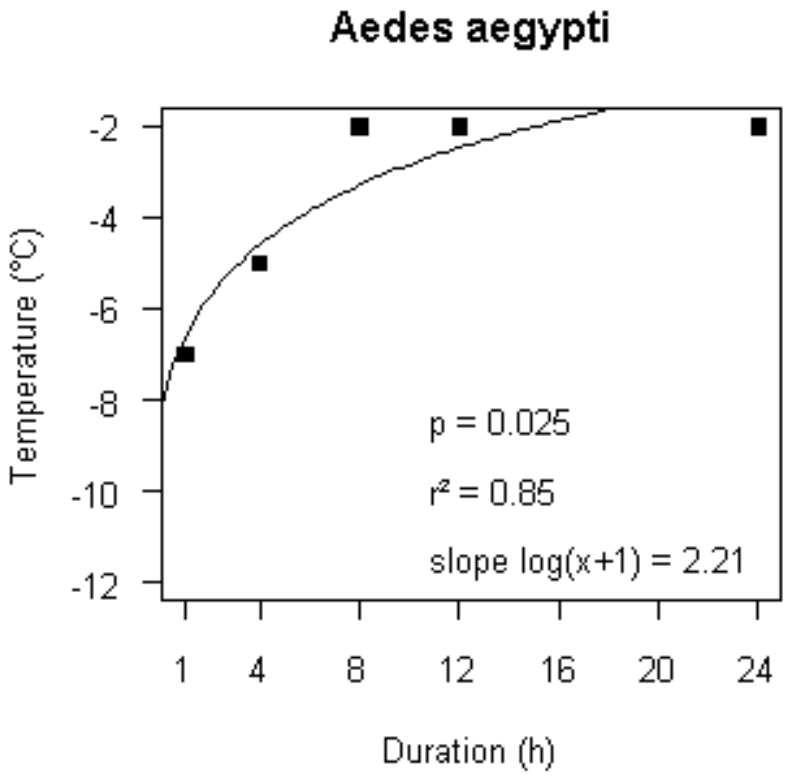
Low Temperature Survival



Thomas et al. (2012) ***Parasites & Vectors***

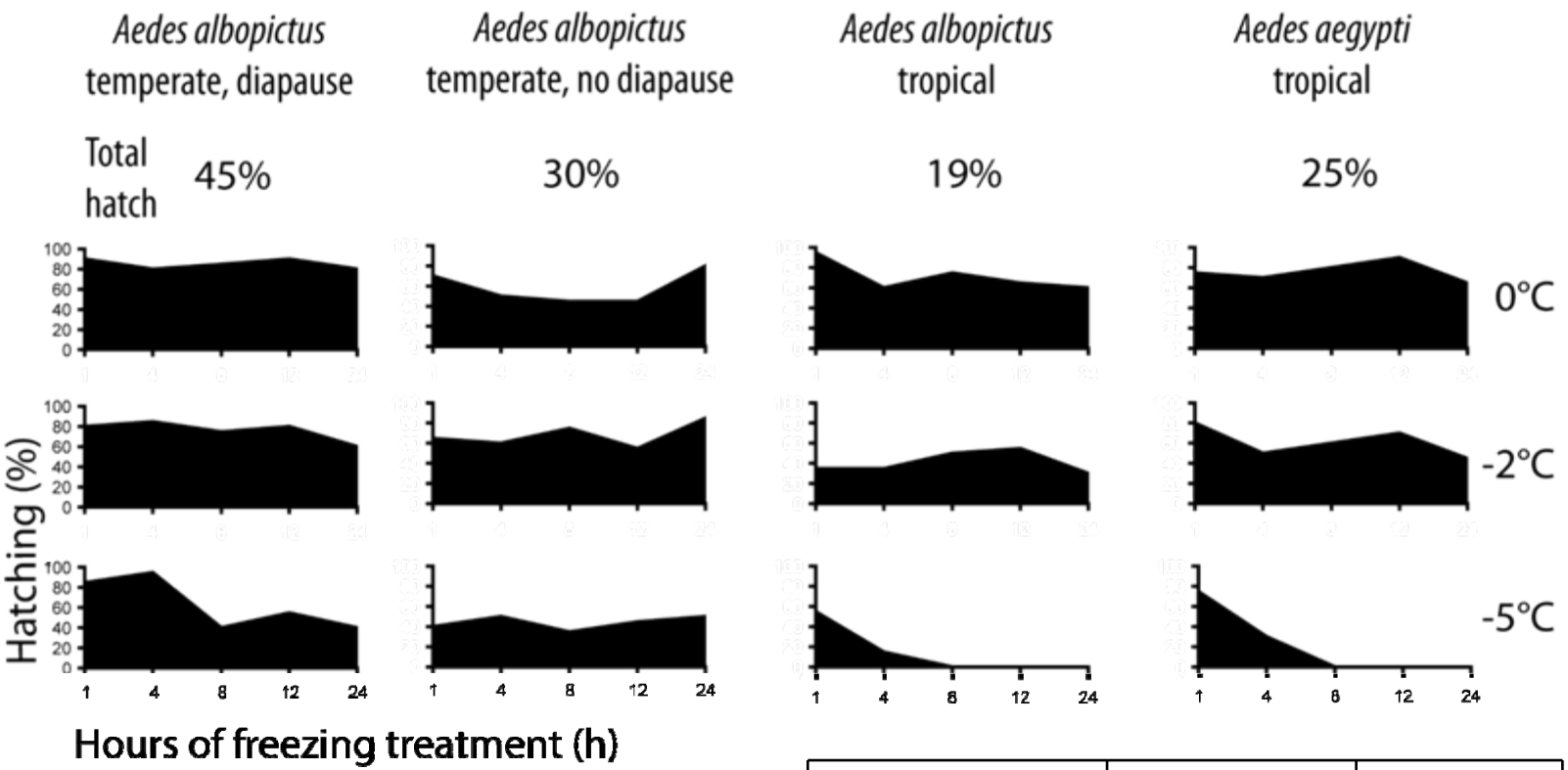
Low Temperature Survival





Thomas et al. (2012) ***Parasites & Vectors***

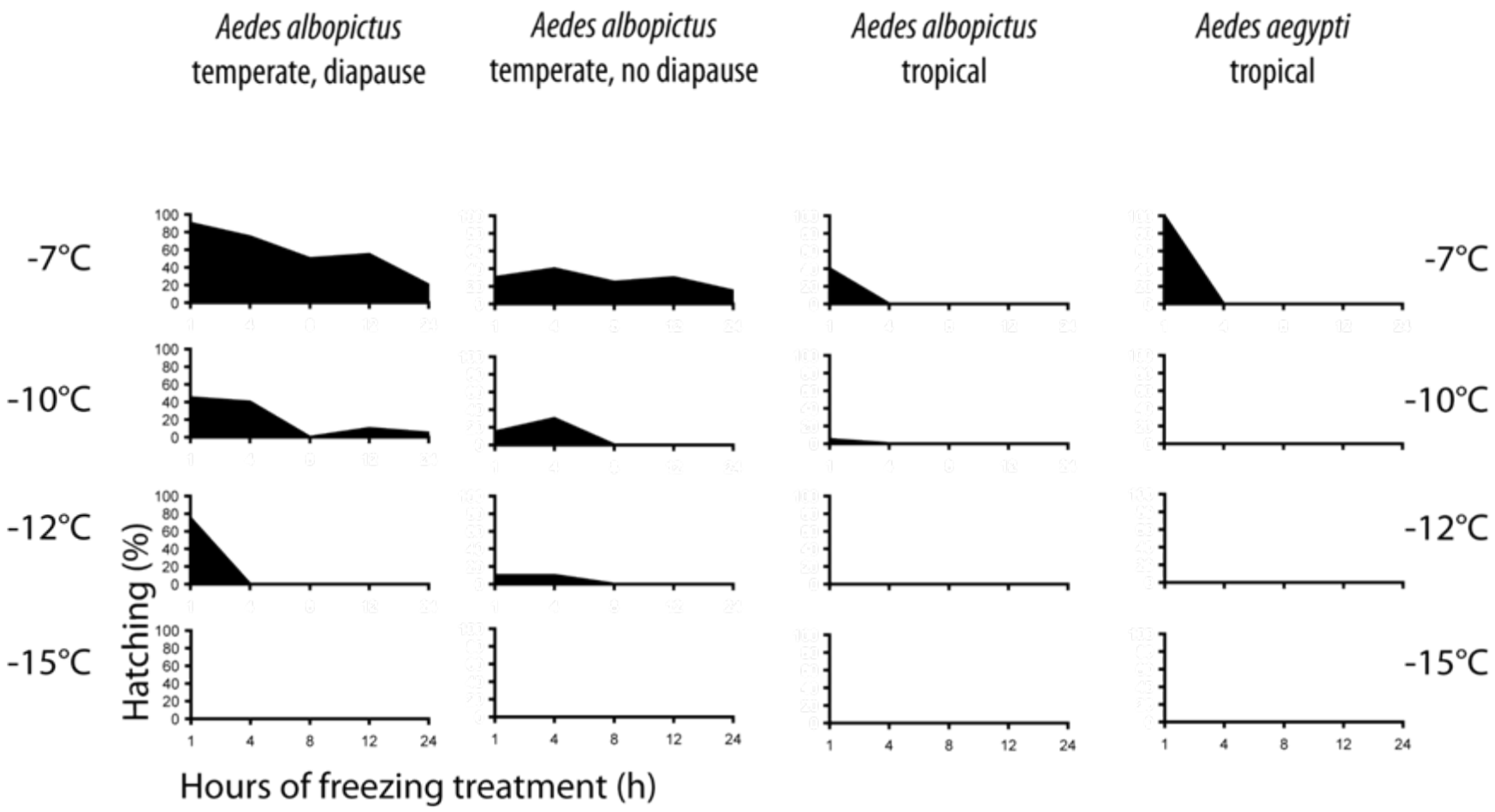
Hatching Success



	F-value	P-value
Temperature	*329.2*	*< 0,0001*
Duration	16.2	*< 0,001*

Thomas et al. (2012) ***Parasites & Vectors***

Hatching Success



Thomas et al. (2012) ***Parasites & Vectors***

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Winter Survival

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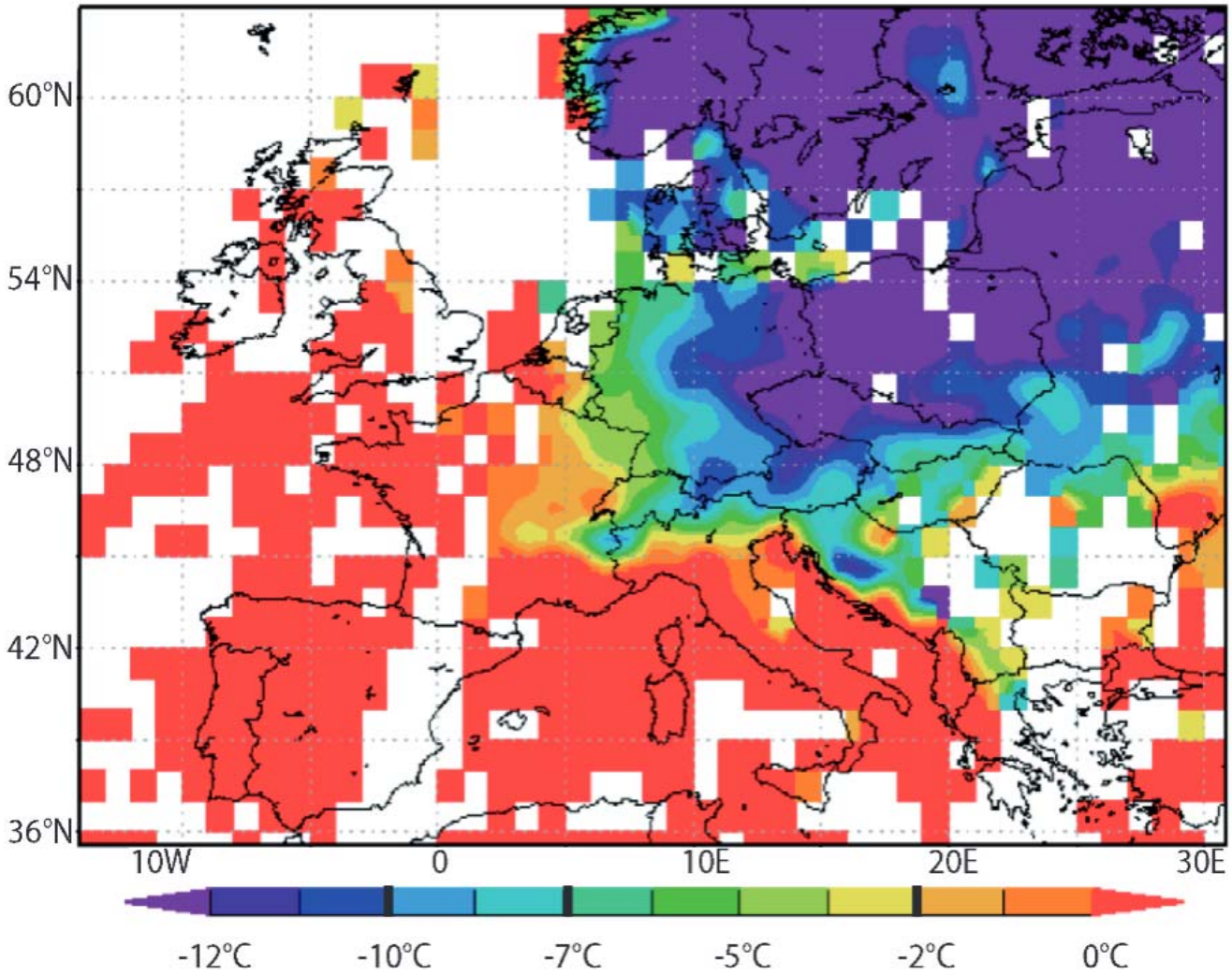
Where would be winter survival of *Aedes albopictus* possible?



Surface air temperature

EUROPE
coldest night
in 2011
02-23

Thomas et al. (2012) ***Parasites & Vectors***

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Winter Survival

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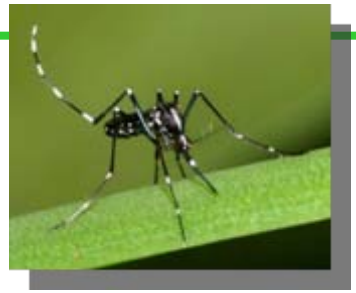
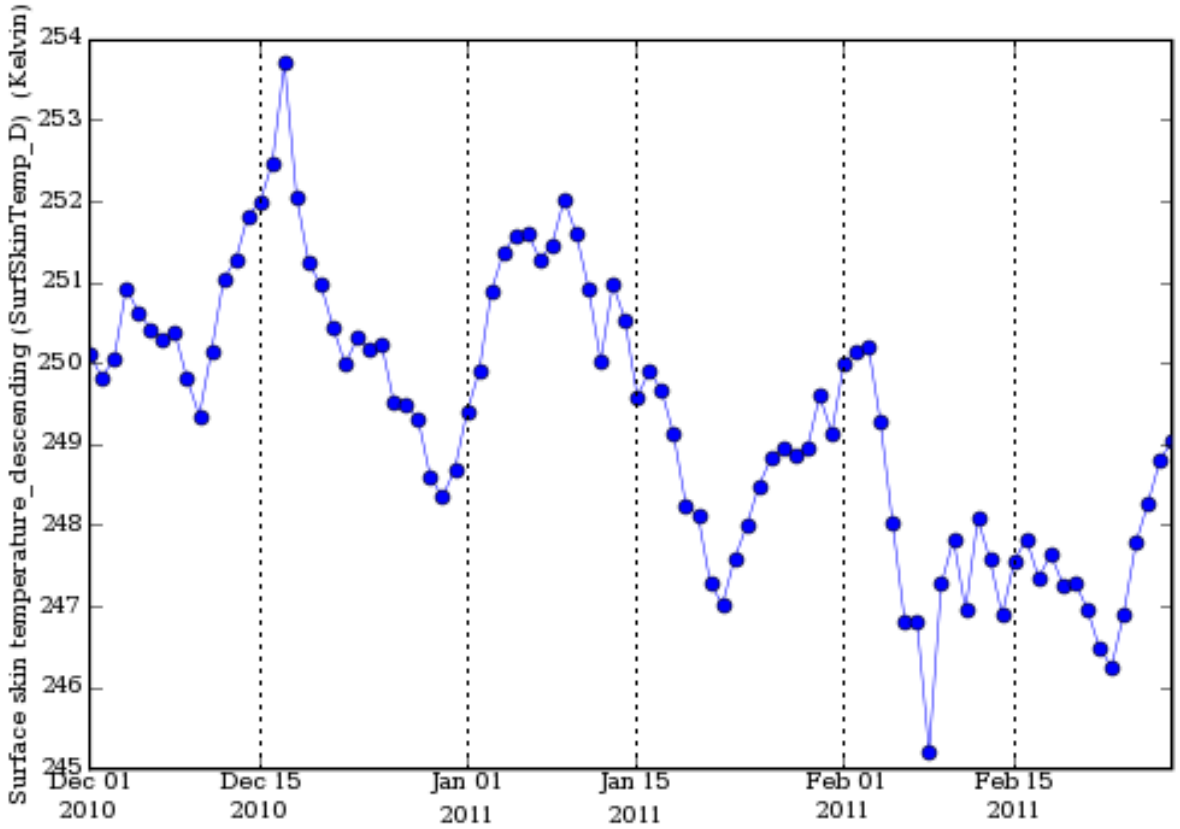
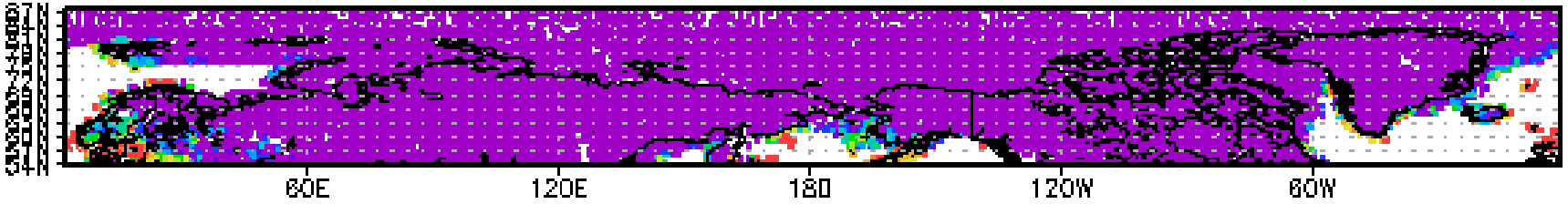


Surface air temperature



ARCTIC
coldest night
in 02/2011
02-06



http://daac.gsfc.nasa.gov/giovanni

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Winter Survival

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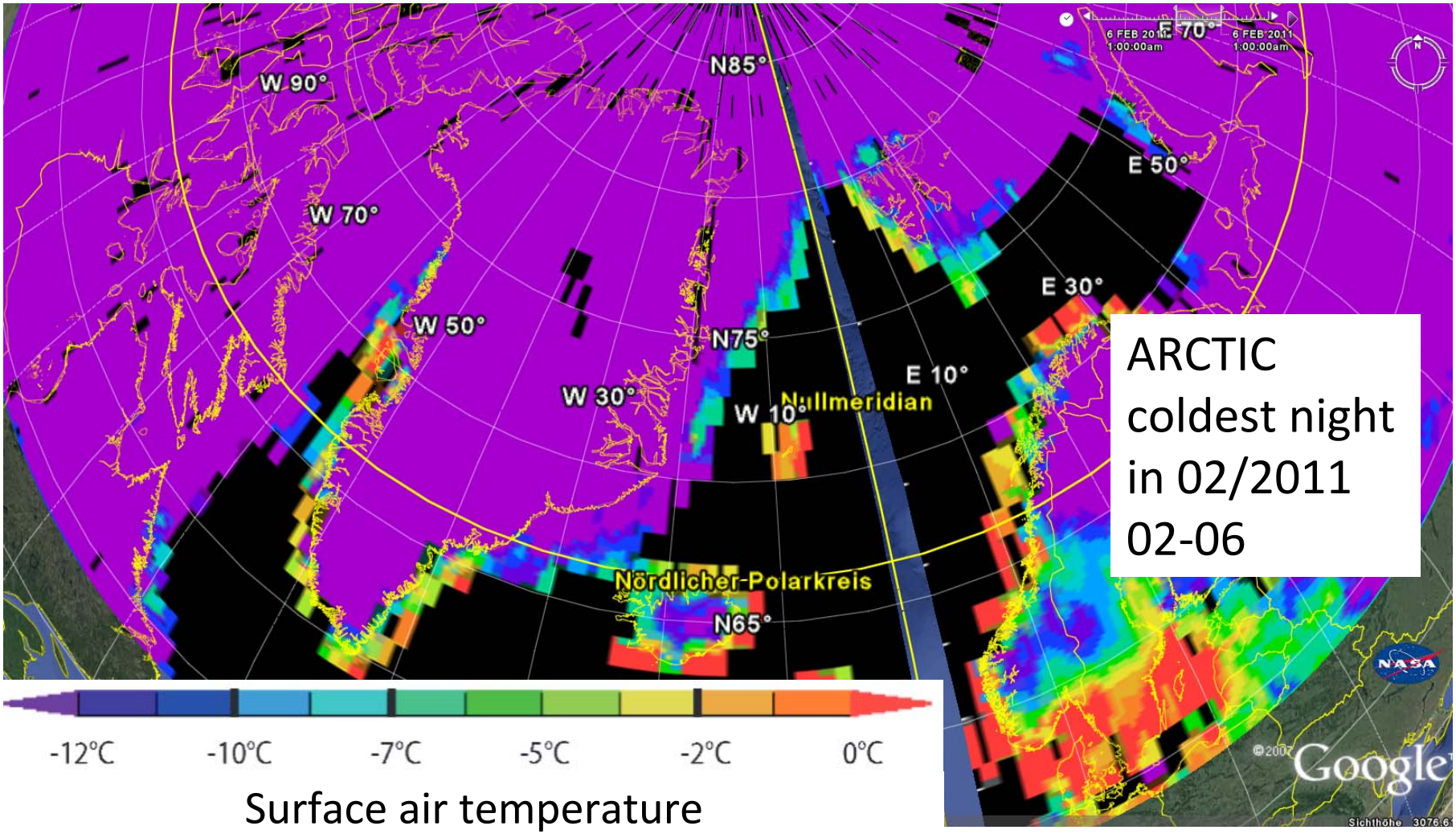

Surface air temperature

ARCTIC coldest night in 02/2011 02-06

http://daac.gsfc.nasa.gov/giovanni

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Winter Survival

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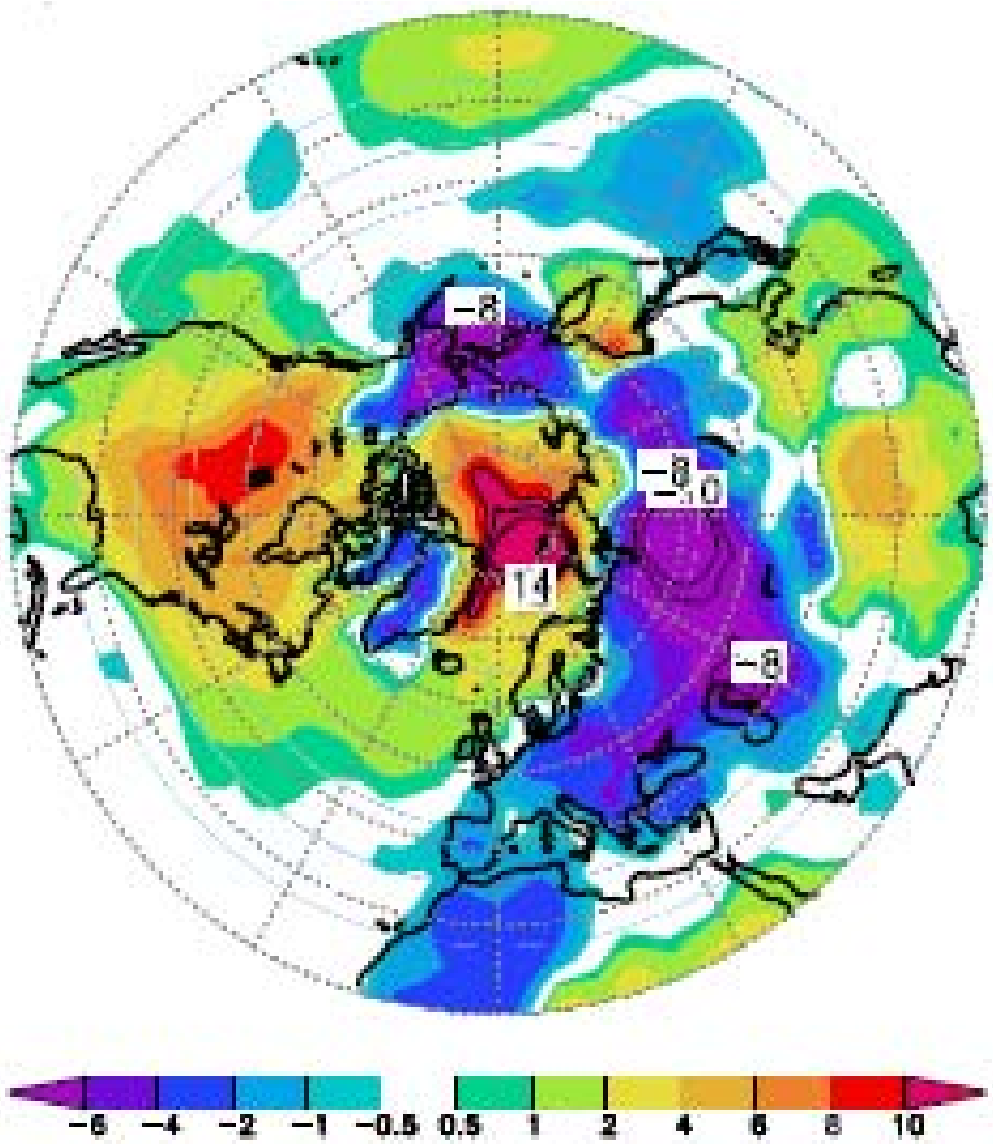
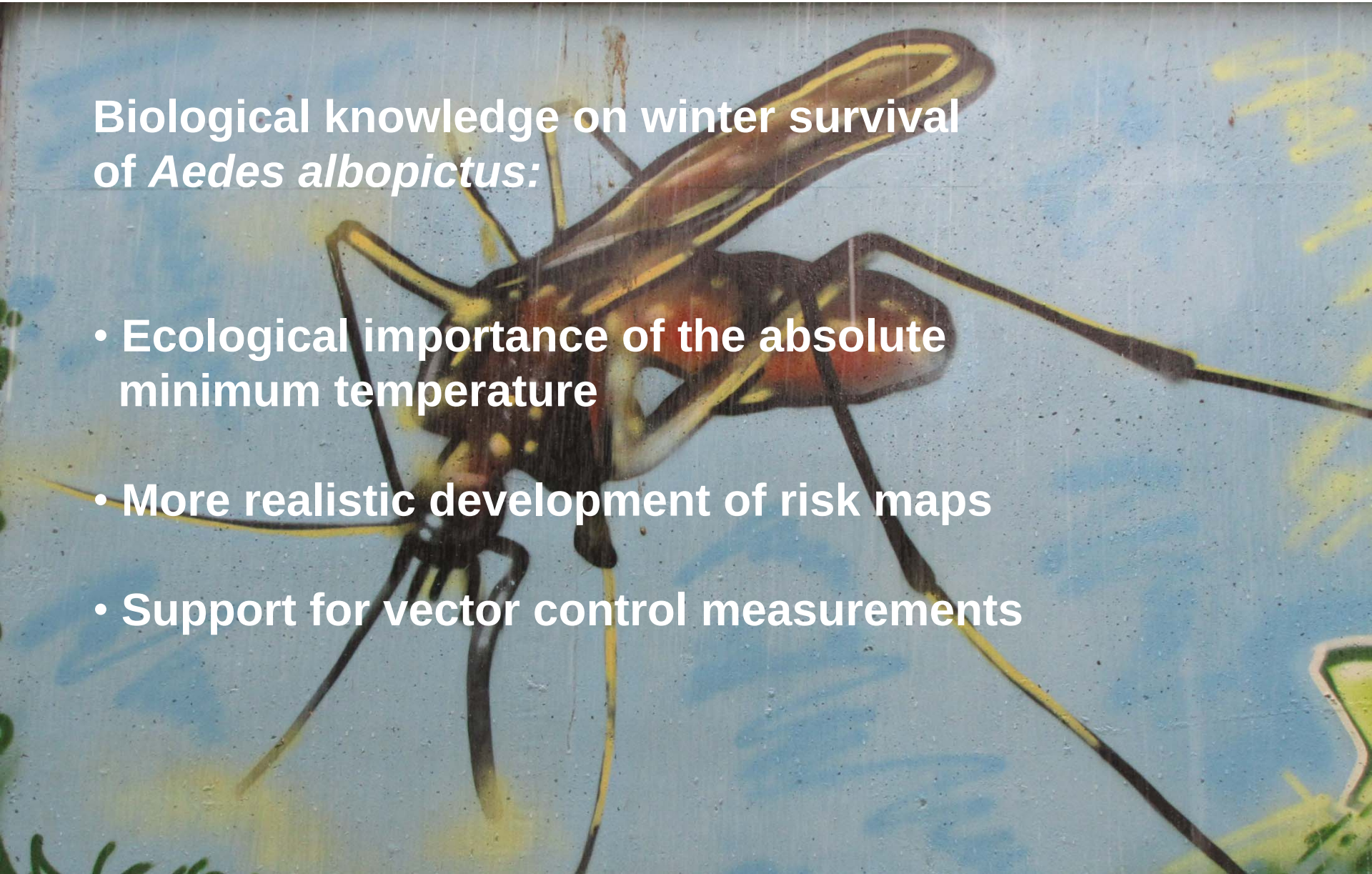


ARCTIC
SAT anomaly
in 2006
January

Petoukhov & Semenov 2010 J Geophys Res - Atmos

Conclusion

Conclusion



Biological knowledge on winter survival of *Aedes albopictus:*

- **Ecological importance of the absolute minimum temperature**
- **More realistic development of risk maps**
- **Support for vector control measurements**

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Winter Ecology

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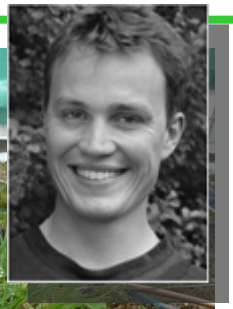
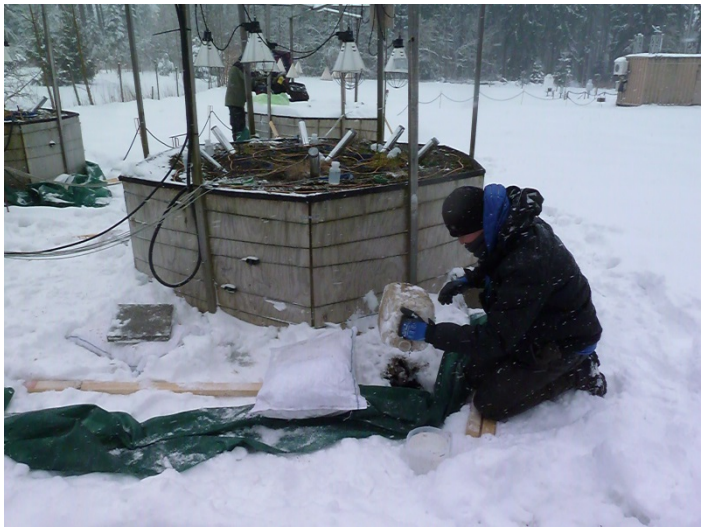
and Environmental Research

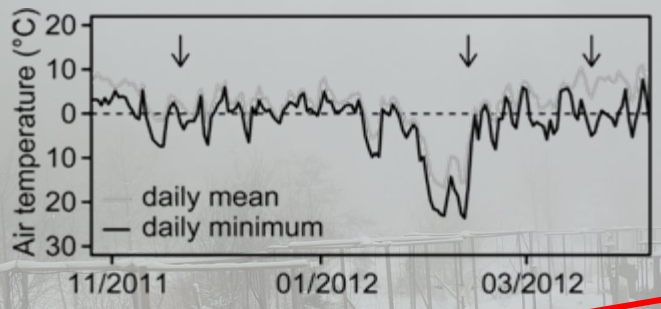


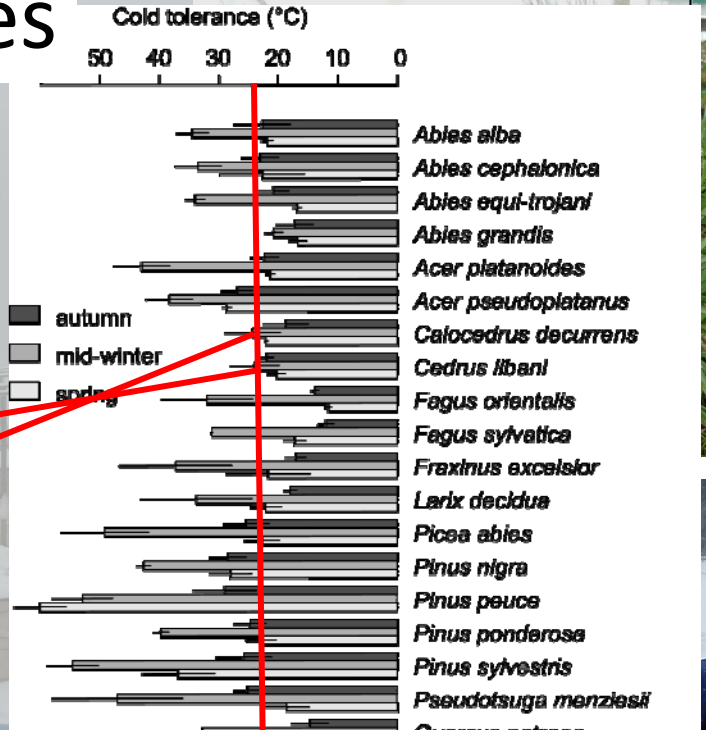
EVENT



Winter Ecology

Cold Acclimation of Trees

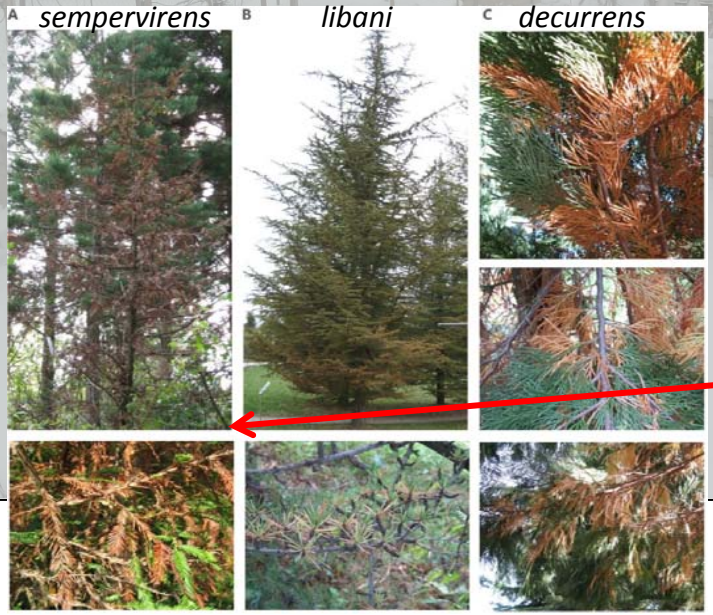


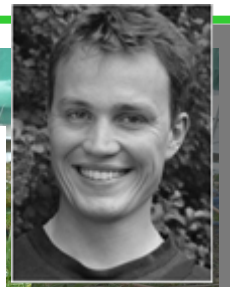


Sequoia sempervirens

Cedrus libani

Calocedrus decurrens





Ecology and Evolution

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Local adaptations to frost in marginal and central populations of the dominant forest tree *Fagus sylvatica* L. as affected by temperature and extreme drought in common garden experiments

Juergen Kreyling[1], Constanze Buhk[2], Sabrina Backhaus[3], Martin Hallinger[4], Gerhard Huber[5], Lukas Huber[2], Anke Jentsch[3], Monika Konnert[5], Daniel Thiel[5], Martin Wilmking[4] & Carl Beierkuhnlein[1]

[1]Biogeography, BayCEER, University of Bayreuth, Bayreuth, Germany
[2]Geoecology/Physical Geography, University of Landau, Landau, Germany
[3]Disturbance Ecology, BayCEER, University of Bayreuth, Bayreuth, Germany
[4]Landscape Ecology, University of Greifswald, Greifswald, Germany
[5]Bavarian Institute for Forest Seeding and Planting (ASP), Teisendorf, Germany

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Team

Bayceer
Bayreuth Center of Ecology and Environmental Research

Prof. Dr. Carl Beierkuhnlein
Department of Biogeography

Dr. habil Jürgen Kreyling
Winter Ecology

Nils Tjaden
Vector-borne Diseases

Anja Jaeschke
Biogeographical Modelling

Reinhold Stahlmann
GIS

University of Bayreuth, Germany
Biogeography
stephanie.thomas@uni-bayreuth.de
0049 921 552307

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Publications

Bayceer
Bayreuth Center of Ecology and Environmental Research

Fischer D., Thomas S.M., Neteler M., Tjaden N.B., Beierkuhnlein C. (2014):
Climatic suitability of Aedes albopictus in Europe referring to climate change projections: Comparison of mechanistic and correlative niche modelling approaches.
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Thomas S.M., Beierkuhnlein C. (2013):
Predicting ectotherm disease vector spread - Benefits from multidisciplinary approaches and directions forward.
Naturwissenschaften 100(5):395-405.

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PLOS Neglected Tropical Diseases 7(6): e2207.

Fischer D., Thomas S.M., Suk J.E., Sudre B., Hess A., Tjaden B., Beierkuhnlein C., Semenza J.C. (2013):
Climate change effects on Chikungunya transmission in Europe: Geospatial analysis of vector´s climatic suitability and virus´ temperature requirements.
International Journal of Health Geographics 12(51).

Thomas, S.M., Obermayr, U; Fischer, D; Kreyling, J; Beierkuhnlein, C (2012):
Low-temperature threshold for egg survival of a post-diapause and non-diapause European aedine strain, Aedes albopictus (Diptera: Culicidae)
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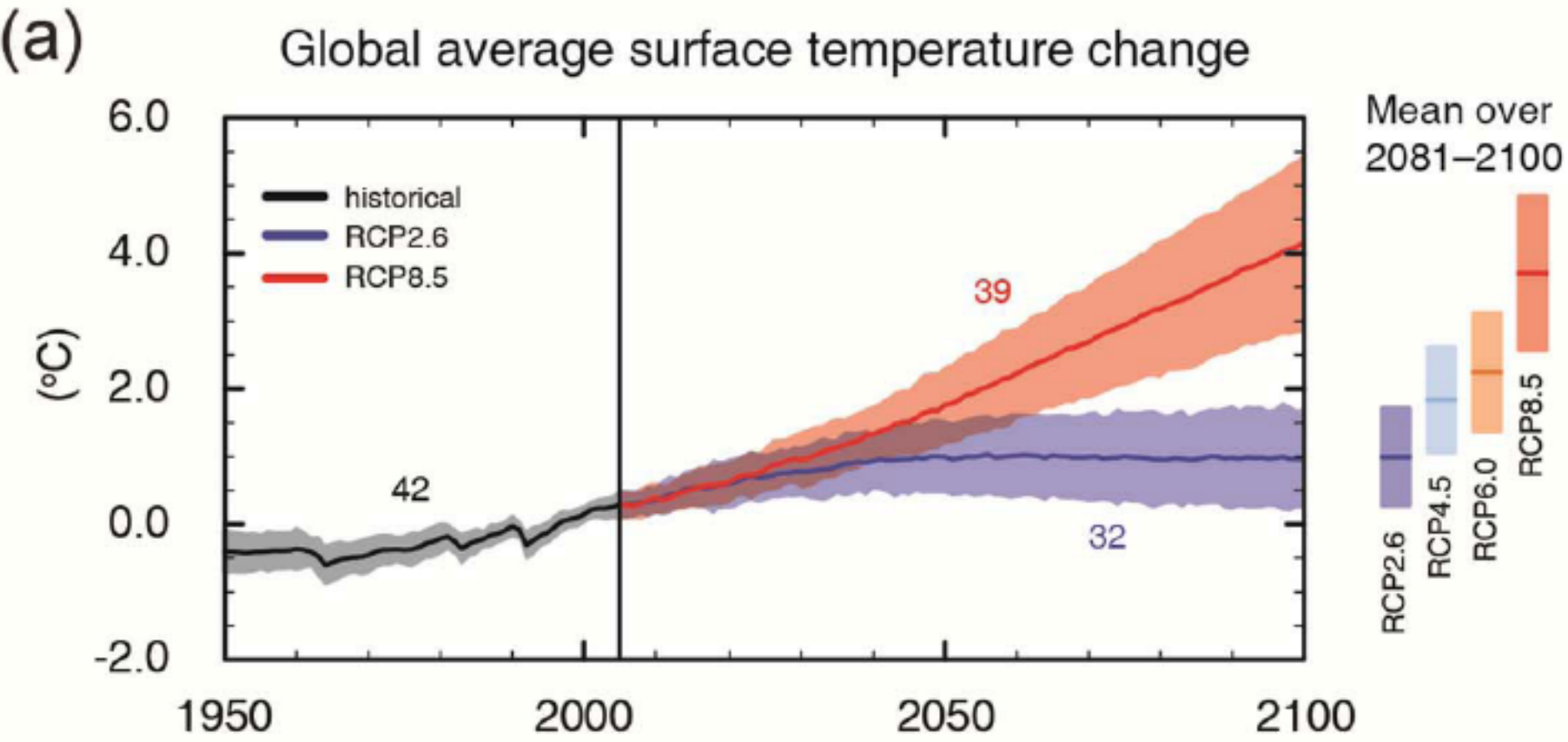
Fischer, D., Thomas, S.M., Niemitz, F., Reineking, B., Beierkuhnlein, C (2011):
Projection of climatic suitability for Aedes albopictus Skuse (Culicidae) in Europe under climate change conditions
Global and Planetary Change, 78(1-2), 54-64.

IPCC Scenarios



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On the way

• Globalisation of trade and traffic with unintended introduction of vectors and pathogens

• Species range shift towards poles, animal husbandry expand into the Arctic, domestic pets follow the people

• Climate change shifts areas at risk for vector-borne diseases

• Knowledge of suitable areas for new vector establishment and disease transmission can focus monitoring and surveillance

• Biosecurity measurements at habours and airports can reduce the risk of introduction