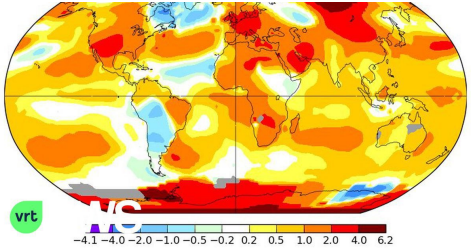
Evolutie als een biologische buffer bij klimaatopwarming?

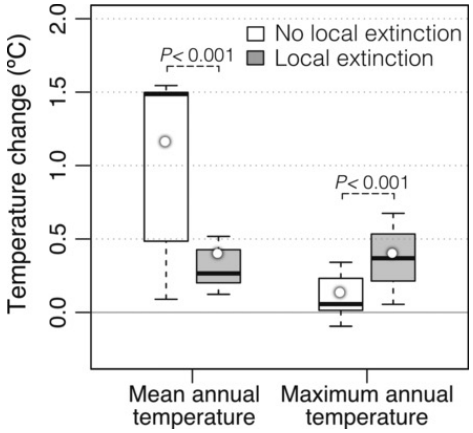
Eco-**evolutionaire** dynamieken en klimaatverandering in een stedelijke omgeving

Kristien I. Brans & Luc De Meester
Laboratory of Aquatic Ecology, Evolution and Conservation,
KU Leuven Belgium

INBO – Klimaatstudiedag 7 Oktober 2021



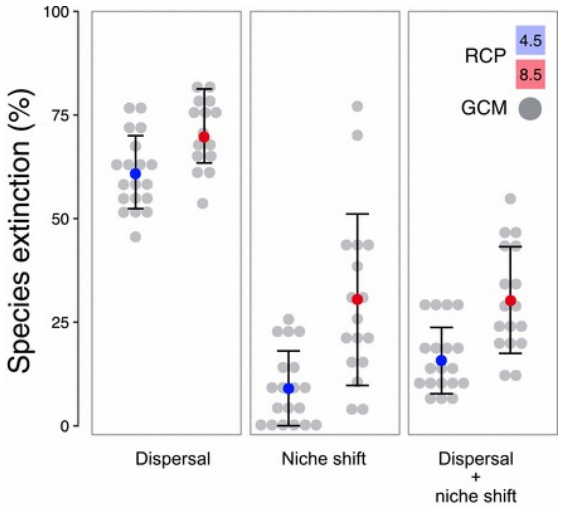
Biotische responsen



Extinctie (Tmax!)

'The Sixt Extinction' (Elizabeth Kolbert)

versnelling (1/6)



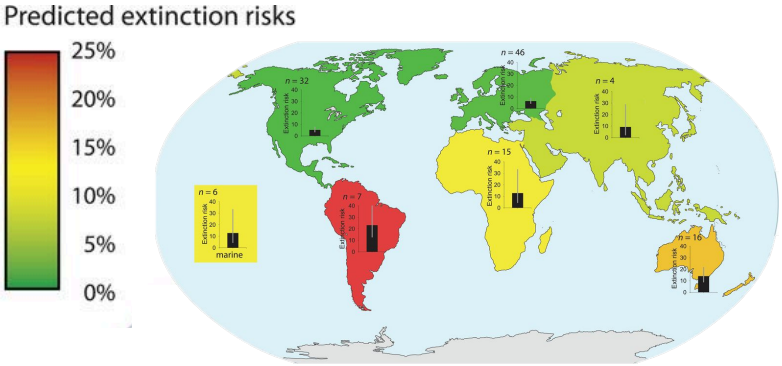
Klimaat-geïnduceerde migratie (range shifts)

'compelling redistribution of life on earth'

Genetische adaptatie

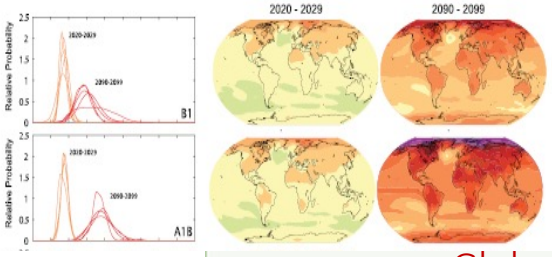
buffer exctinctie

interactie met migratie

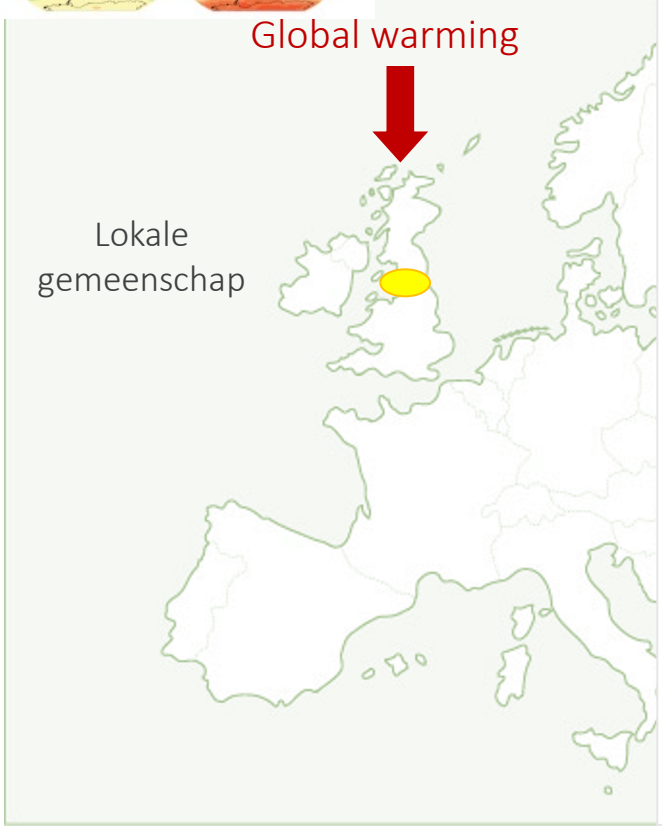


Romàn-Palacios & Wiens 2020 PNAS
Urban 2015 Science

Evoluerende metagemeenschappen: gemeenschapsecologie, evolutie, ruimte



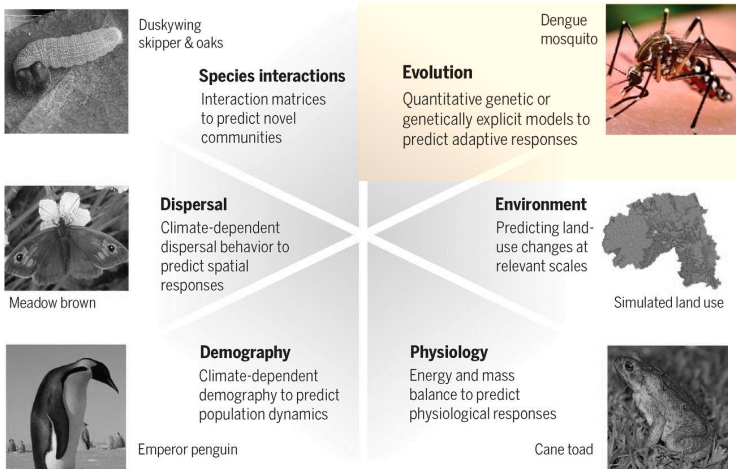
Global warming



Lokale processen

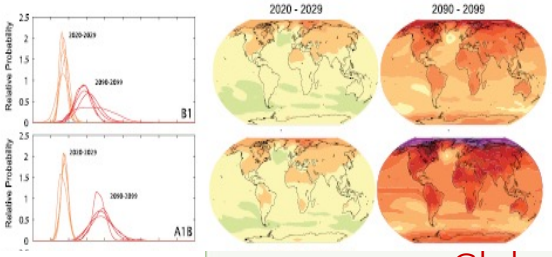
a) species sorting (gemeenschapsniveau)

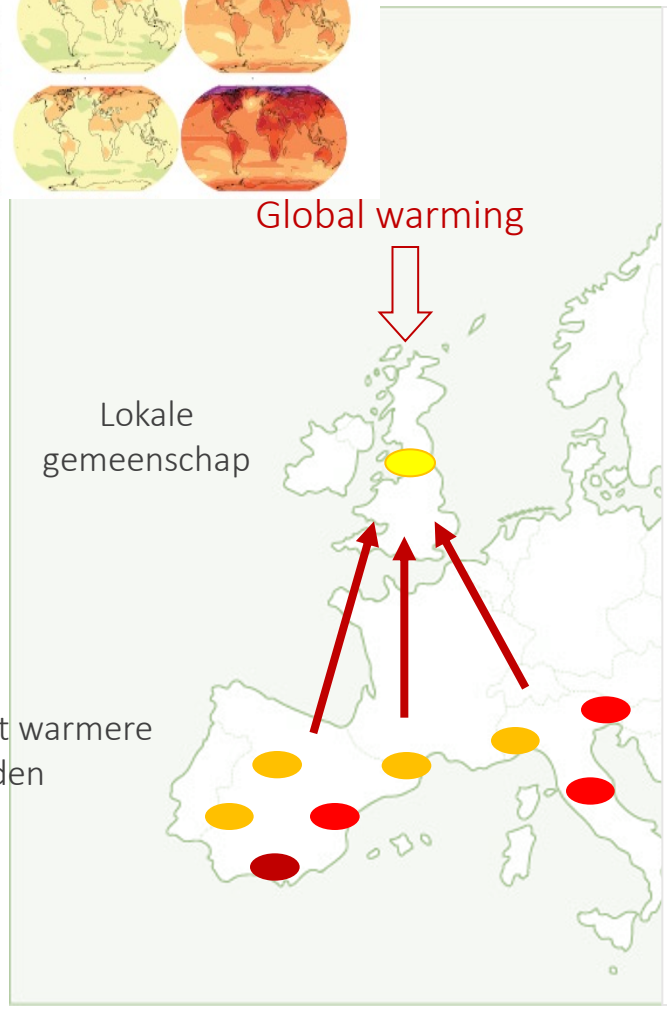
b) **micro-evolutie** (populatie niveau)



De Meester et al. 2011 Integrative and Comparative Biology
Urban et al. 2012 Evolutionary Applications, 2016 Science

Evoluerende metagemeenschappen: gemeenschapsecologie, evolutie, ruimte





Lokale processen

a) species sorting (gemeenschapsniveau)

b) micro-evolutie (populatie niveau)

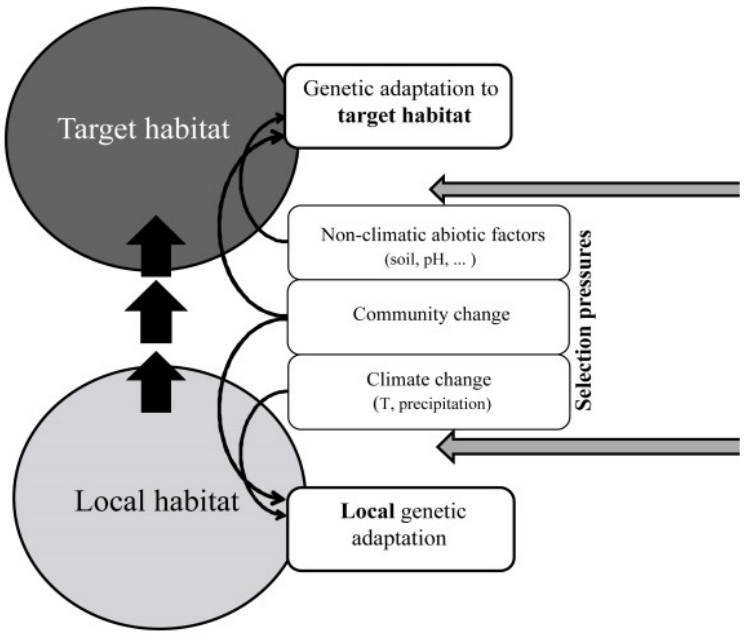
2. Regionale processen *[Migratie]*

a) Immigratie soorten (dispersie)

b) immigratie genotypes (gene flow)

De Meester et al. 2011 Integrative and Comparative Biology
Urban et al. 2012 Evolutionary Applications, 2016 Science

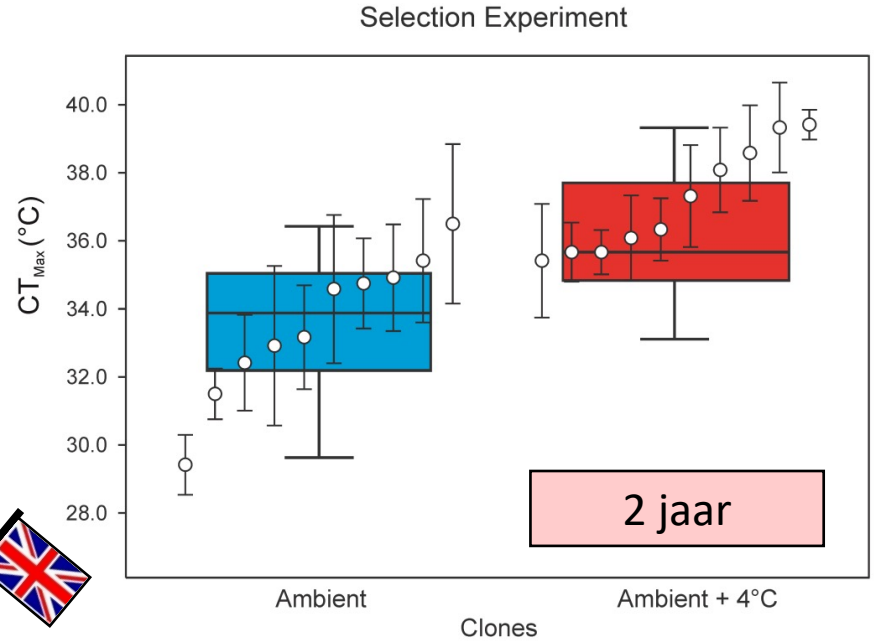
Migratie en evolutie



De Meester, Stoks & Brans 2019 Integrative Zoology

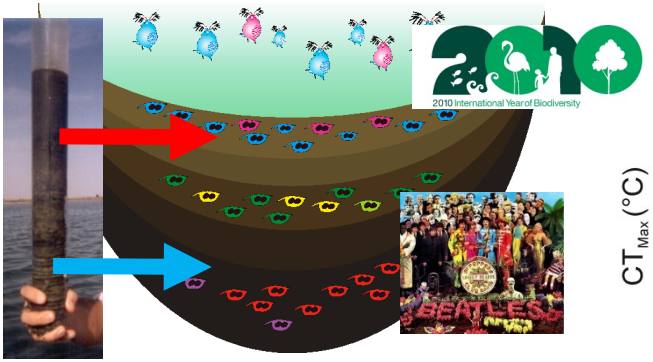
Klimaatopwarming: evolutie van hittetolerantie?

A. Selectie experiment

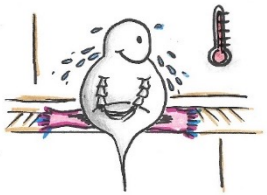


Potentieel om zich aan genetisch aan te passen aan klimaatopwarming

B. Resurrectie Ecologie



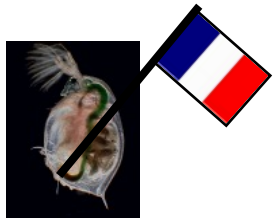
Genetische adaptatie aan klimaatopwarming in *Daphnia* **in afgelopen decennia**

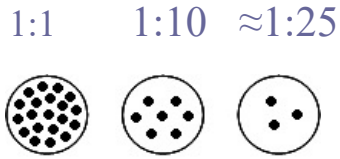


Geerts et al. 2015 Nature Climate Change
Zhang et al. 2016 Evolutionary Applications

Belangrijk? Lokale vs. regionale responsen

In welke mate zijn populaties die zich genetisch aan pasten (1.5 jaar) aan een hogere temperatuur resilient tegen migratie en vestiging van zuidelijke genotypes?



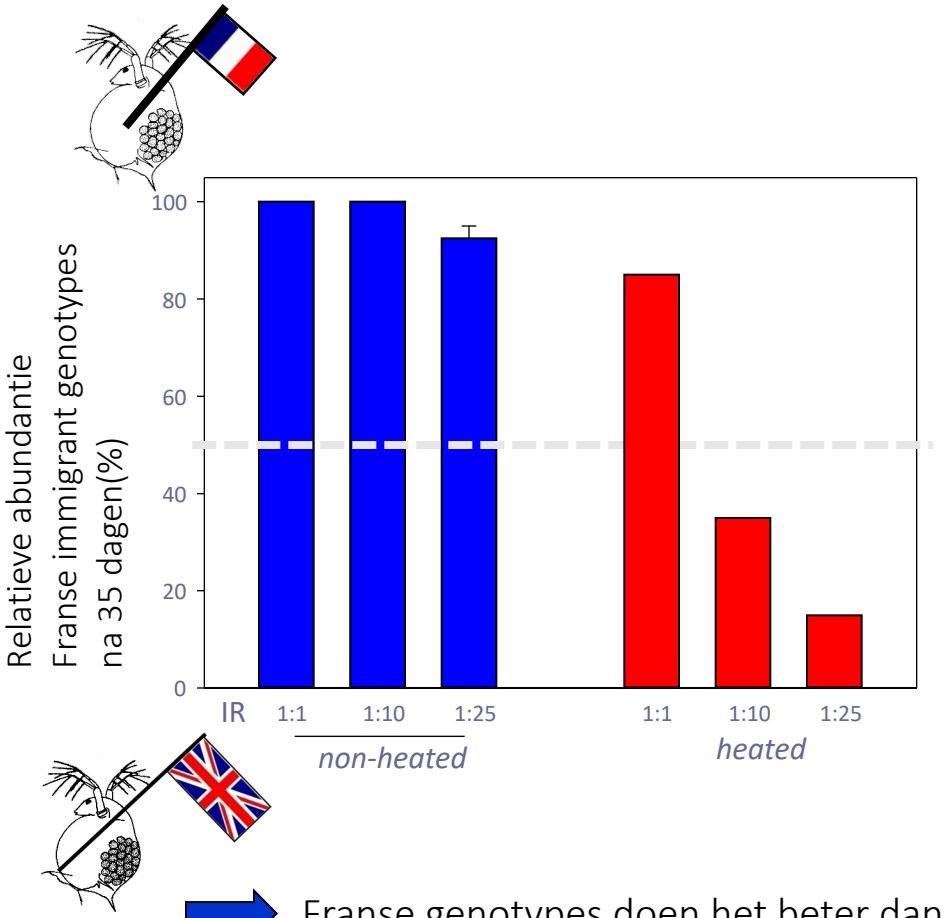


Competitie experiment

+4°C

Van Doorsaer et al. 2009 Global Change Biology

1.5 jaar genetische adaptatie verandert lokale vs. regionale dynamieken

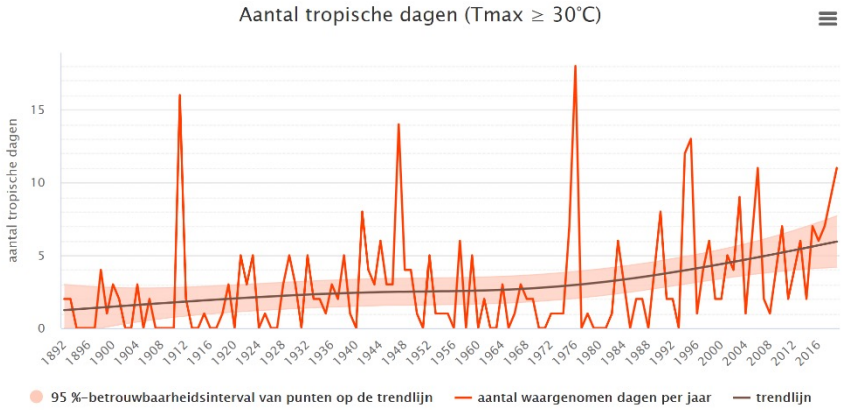


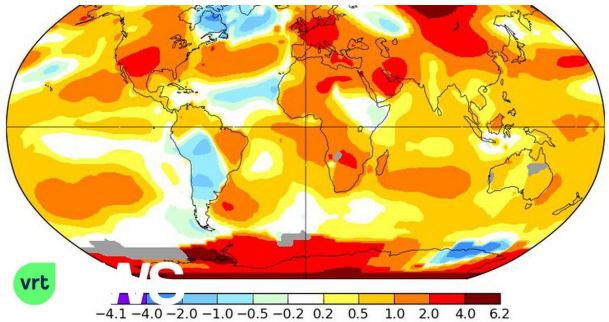
Franse genotypes doen het beter dan UK genotypes (bij +4°C) ….

Maar Franse dominantie verzwakt in mesocoms met UK residente genotypes die zich aan pasten aan opwarming

Snelle evolutie kan klimaatresponsen dus meer LOKAAL maken!

Van Doorsaer et al. 2009 Global Change Biology





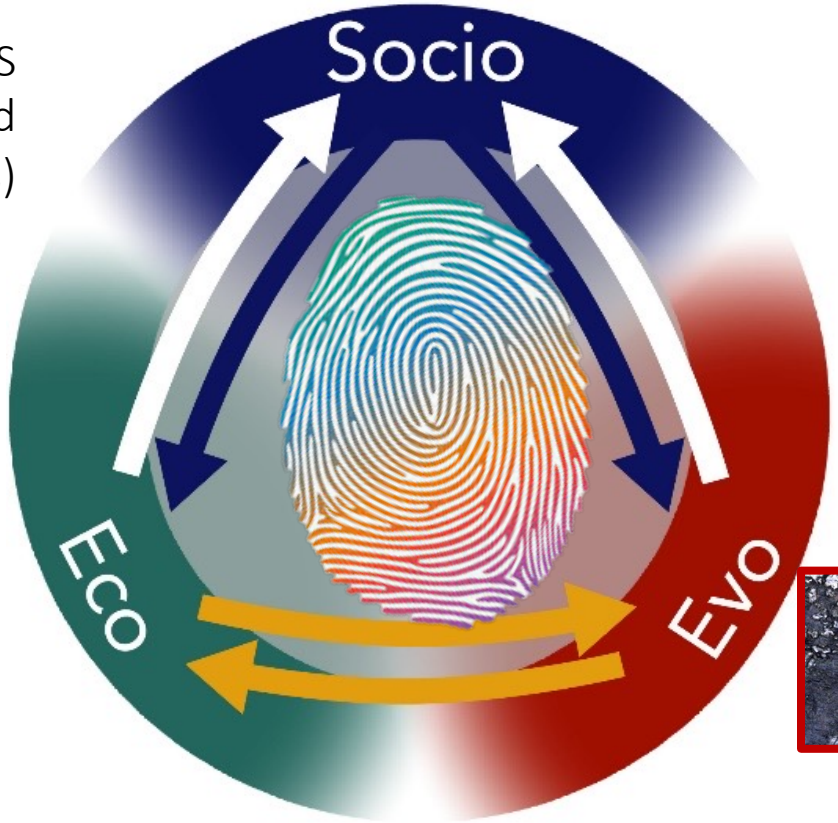
Brouwers et al. 2015, Lauwaet et al. 2018, MIRA

De stadsomgeving: ‘spontaan’ en boeiend testvat voor predicties klimaatresponsen en adaptatie?

Economie Cultuur Beleid

Mensen
Sociale patronen en processen

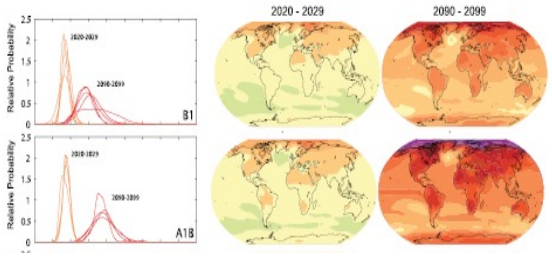
CHANS
(coupled human and natural systems)



'Urban Ecology'

'Urban Evolution'

Des Roches et al. 2020 Evolutionary Applications



LOKAAL

Habitat verlies en fragmentatie

Pollutie
- geluid
- licht
- chemisch

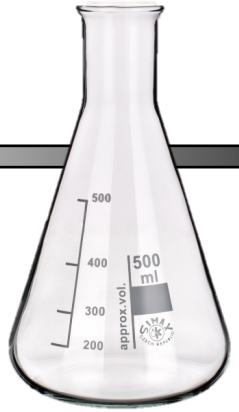
Stedelijk Hitte Eiland effect

Klimaatvariabiliteit: extremen

Hydrologie

Biogeochemische cycli

Eutrofiëring



REGIONAAL - GLOBAAL

Habitat verlies en fragmentatie

Pollutie
- geluid
- licht
- chemisch

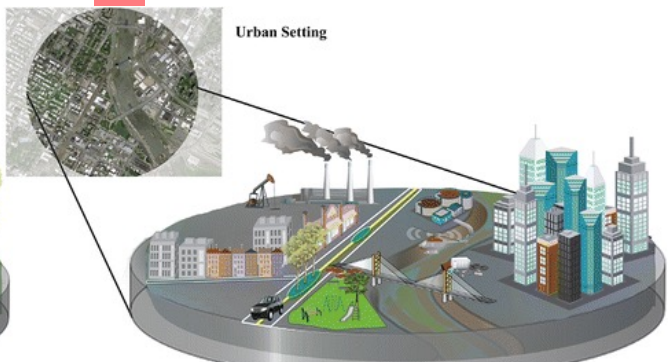
Klimaatopwarming

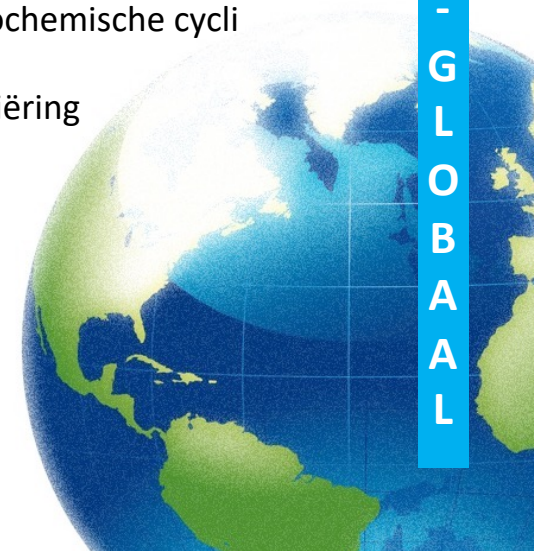
Klimaatvariabiliteit: extremen

Hydrologie

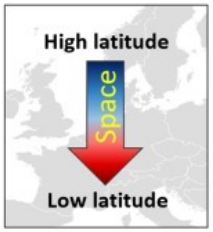
Biogeochemische cycli

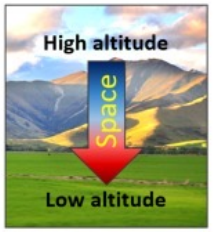
Eutrofiëring





‘Ruimte-voor-tijd’ substituties (Space for Time)

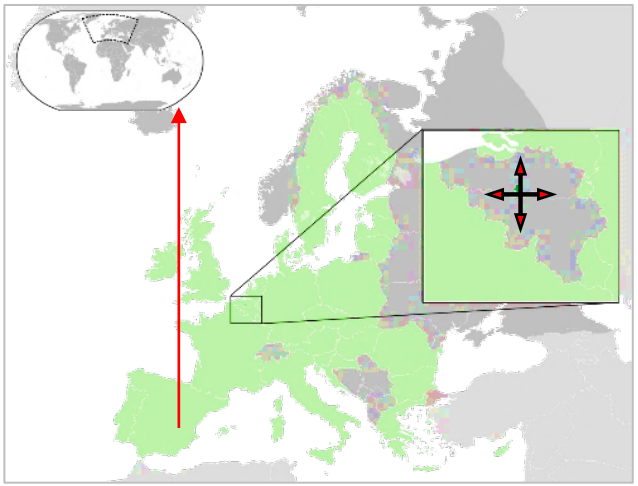


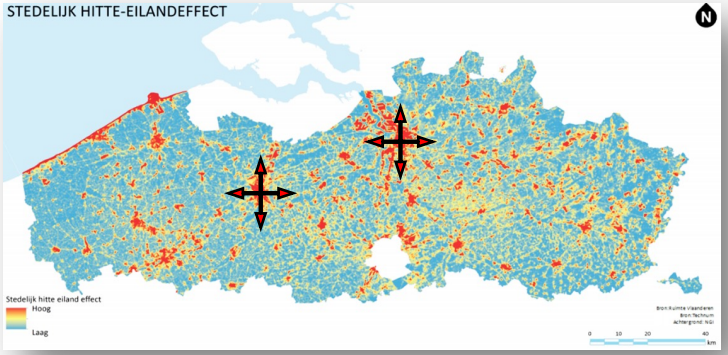


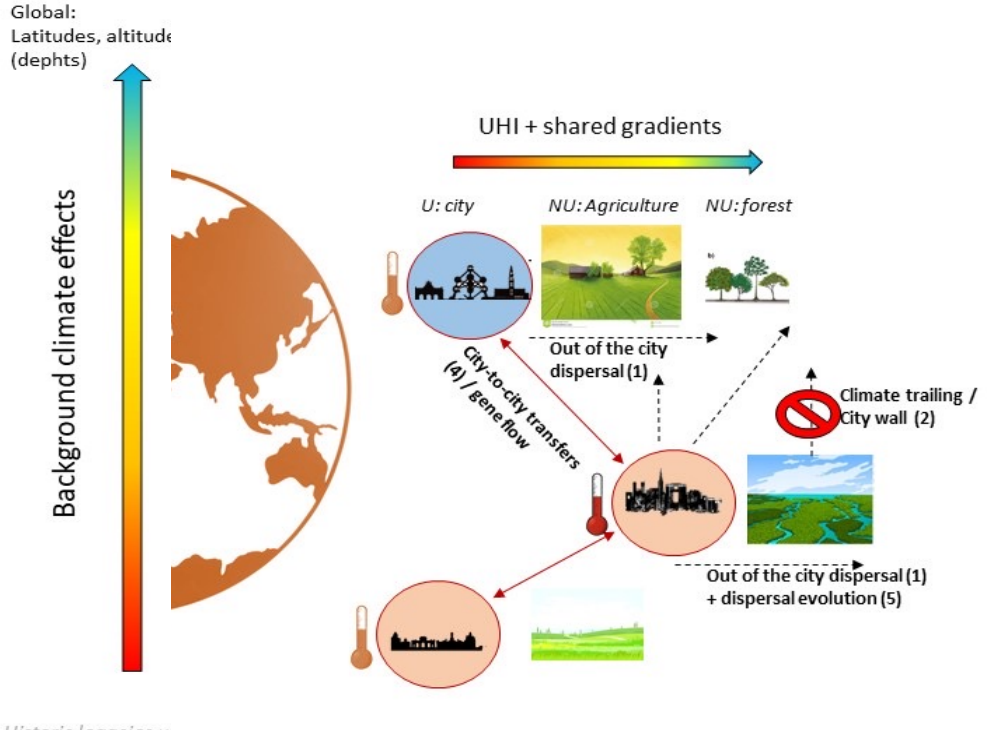
Thermal characteristics	Latitudinal gradient	Altitudinal gradient
Spatial thermal difference of 4°C possible	Yes	Yes
Heat waves	Increases	Increases
Slope thermal gradient	Shallow (> 100 km)	Steep (<1 km)
Daily temperature fluctuation (DTF)	Increases	Not consistent
Annual temperature variation (seasonality)	Decreases	Not consistent
Non-thermal characteristics		
Photoperiod	Changes	Equal
Direct solar radiation and the UV-B fraction	Increases	Decreases
Carbon dioxide levels	Equal	Increases
Oxygen levels	Equal	Increases
Anthropogenic disturbance (e.g. pollution)	Can be disentangled	Can be disentangled
Evolutionary aspects		
Gene flow	Low	Intermediate
Temporal scale of evolution	Centuries	Centuries
Direction of gene flow during historical colonization	Toward colder regions	Toward colder regions
Presence thermal adaptation	12 out of 25 studies	2 out of 5 studies
Methodological aspects		
Distances to be travelled	High	Intermediate
Possibility for replicates	Low	Intermediate

Verheyen et al. 2019 Current Opinion in Insect Science

Interacties: verstedeliiking x klimaatopwarming



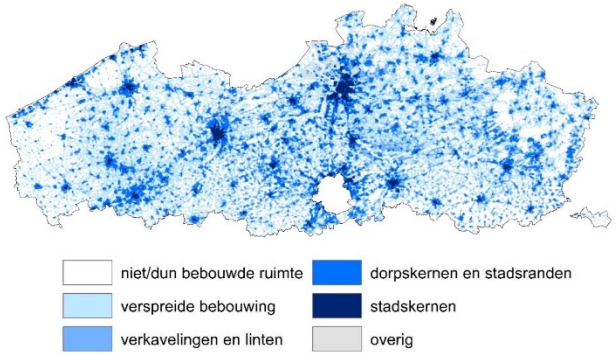




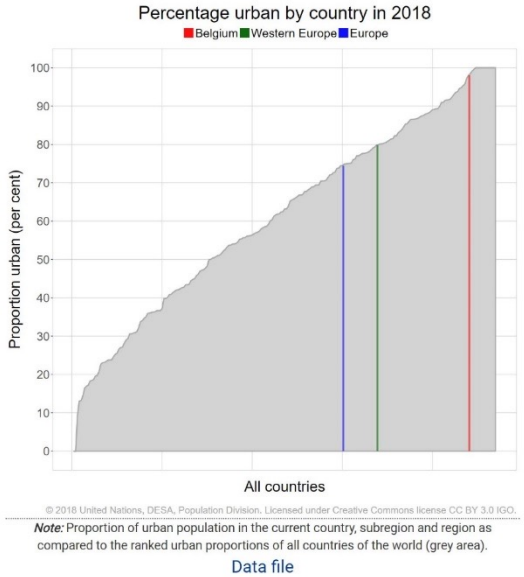
Evoluerende metagemeenschappen

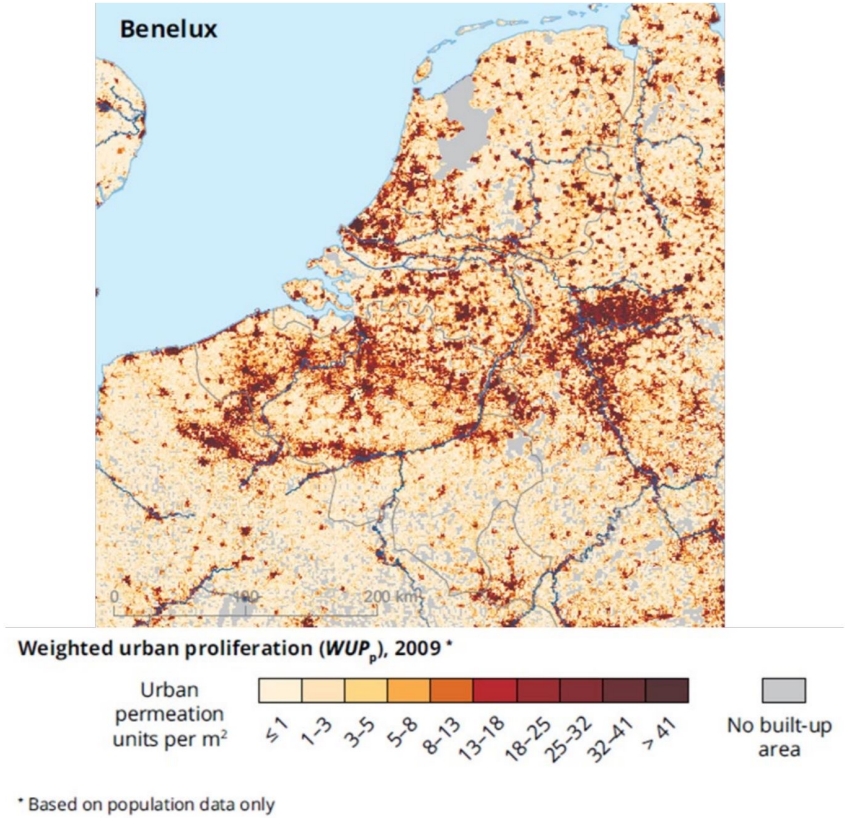
De stadsomgeving: (socio)-eco-evolutionaire dynamieken

‘Metropool Vlaanderen’



Figuur 2: Sprawl typologiekaart voor Vlaanderen

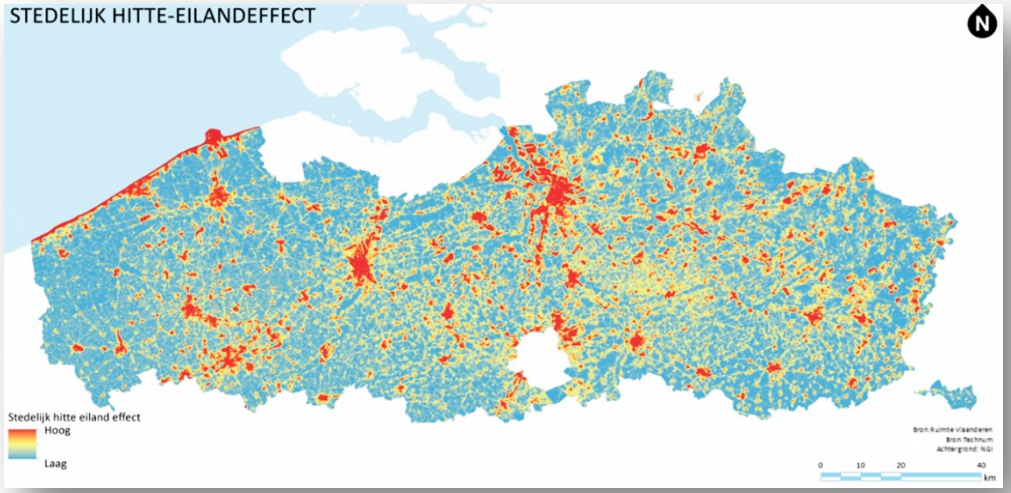




Figuur 1: Urban sprawl in België en omliggende regio’s – EEA-rapport (2016)

Vermeiren et al. 2019, VITO

De verwarming in de stad staat aan…



19.255. Co-ouderschap is daarin een van de belangrijkste factoren.

De tijd dat kinderen van gescheiden ouders tot hun achttiende één verblijfsregeling hadden, is al lang voorbij. Voor ze achttien worden is de hoeveelheid tijd die ze bij hun beide ouders door-

jongste jaren spectaculair.

In 2008 spraken de Belgische jeugdrechters zich 13.217 keer uit over de toekenning van het ouderlijke gezag. In 2012 was dat al 19.255 keer. Van de burgerrechtelijke vonnissen bij de jeugdrechter ging 80 procent over verblijfsregelingen. In 2008 was dat nog 70 procent.

koppels én samenwonende koppels die uit elkaar gaan, komen bij de jeugdrechter terecht

Antwerpse binnenstad tot 8 graden warmer

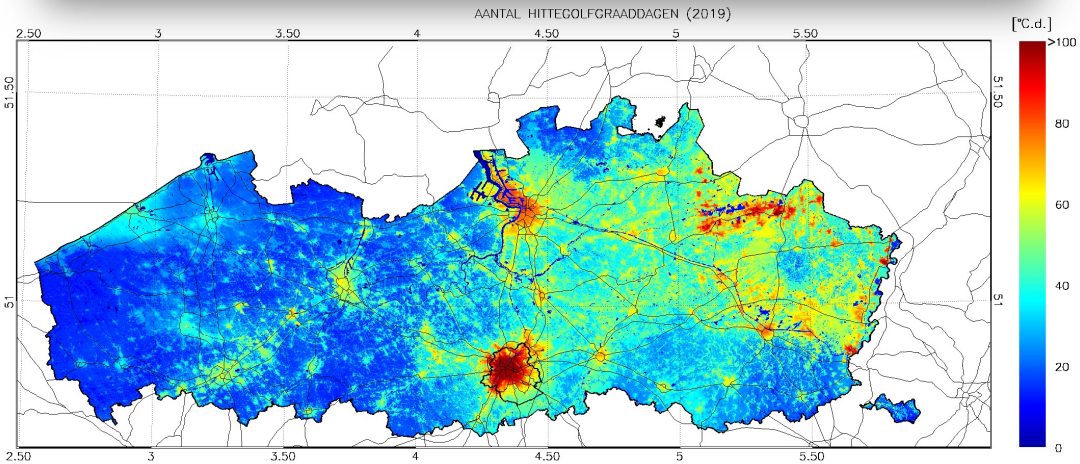
BRUSSEL – In het centrum van Antwerpen is het tijdens de zomer gemiddeld 3,5 graden warmer dan op het platteland. Op hete dagen loopt het verschil zelfs makkelijk op tot ruim 8 graden. Dat is de conclusie van de Vlaamse onderzoeksorganisatie VITO. Die voerde een hittestudie uit in opdracht van de Stad Antwerpen. De studie werd gisteravond aan het stadscollège voorgesteld.

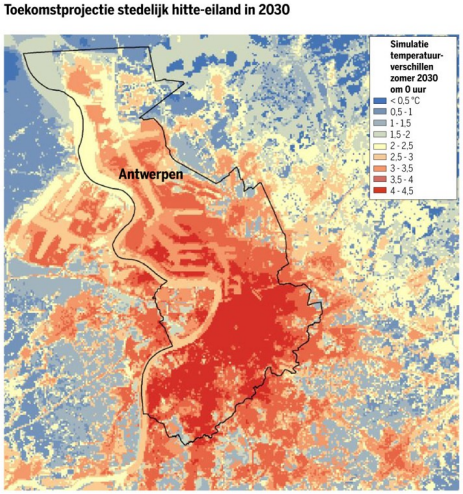
Het temperatuurverschil is vooral het gevolg van de bebouwde en verharde omgeving in de stad. Asfalt en beton nemen de zon gretig op en stoten daarna warmte uit. "Dat effect is duidelijk merkbaar in het Antwerpse havengebied", zegt VITO-onderzoeker Dirk Lauwaet. "Je hebt daar een open vlakte, maar door de enorme hoeveelheden beton en asfalt gaat de temperatuur er pijlsnel de hoogte in."

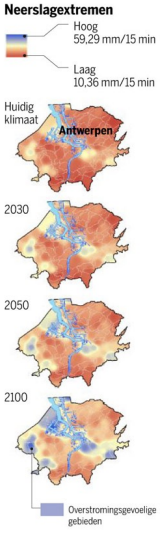
De Antwerpse schepen van Leefmilieu Nabilla Ait Daoud (N-VA) belooft dat het stadsbestuur rekening zal houden met de hittestudie. Zo gaat de schepen na of er nieuwe bepalingen in de bouwcode kunnen komen. Nu al moet het plat dak van elke nieuwe of gerenoveerde woning een daktuin hebben. (SV)

>>FOCUS 12-13

PRIJS: 3,50 EURO ● Nederland: 3,70 euro ● Hoofdredacteur: Yves Desmet ● Uitgave: De Persgroep Publishing ● De Morgen, Brusselsesteenweg 347, 1730 Asse-Kobbegem



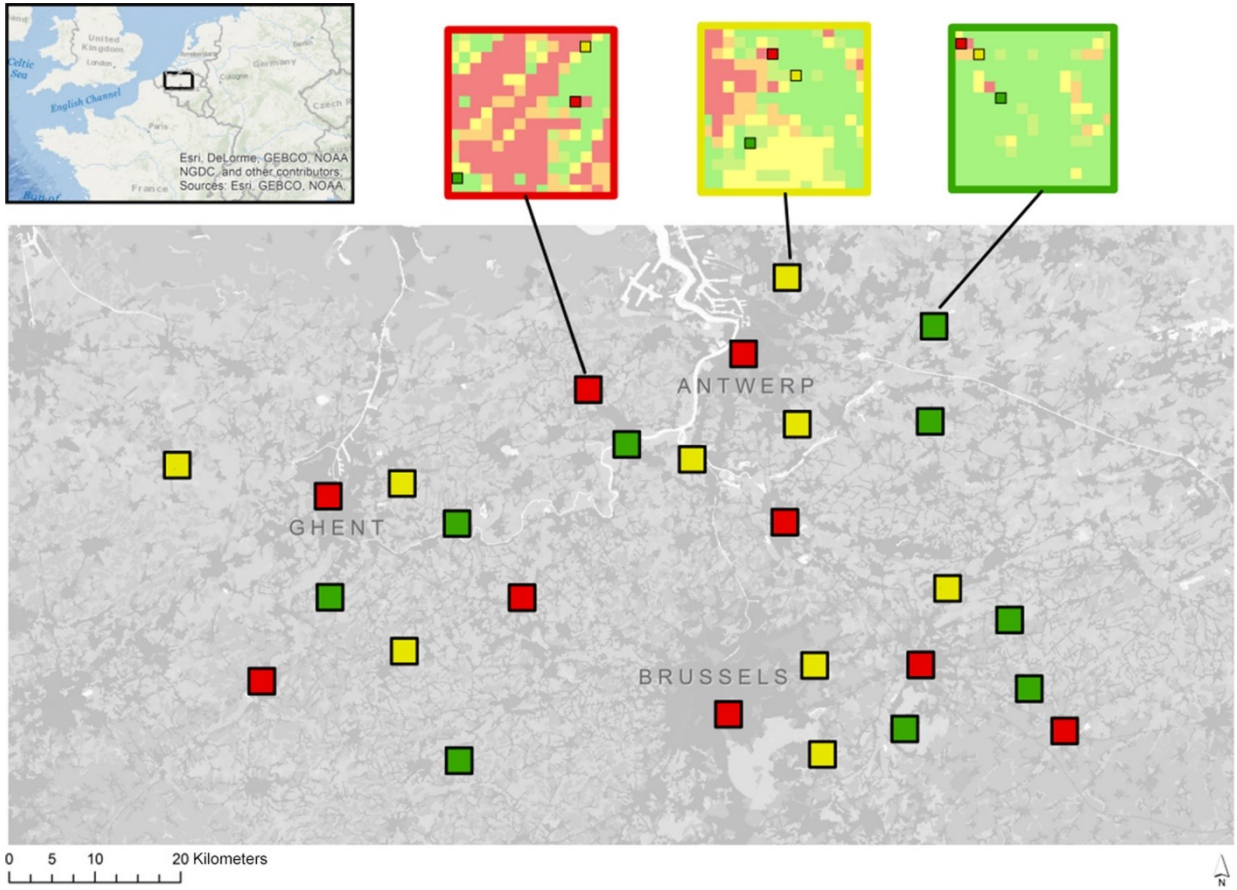




Lauwaet et al. 2018, MIRA

Ecologie en evolutie aan onze voordeur?

Speedy project



Ecologische en evolutionaire responsen!

Meerdere taxonomische groepen

Interuniversitair

Piano et al. 2018 2020 Global Change Biology
Foto's: Per Hoffman Olsen, Christophe Brochard, Olaf Mertens

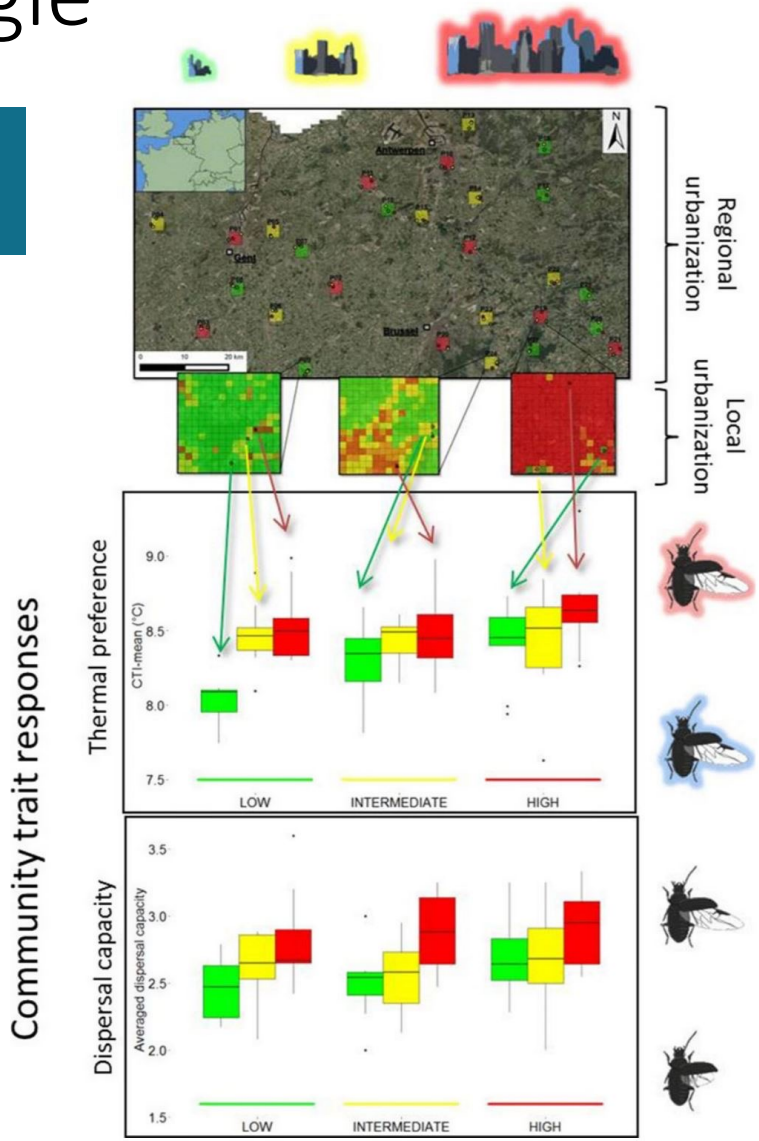
Stadsecologie

Community Weigthed Trait Value

$$\bar{z}_L^j = \sum_i q_{ij} z_{ij}$$

Warmte tolerante soorten

Soorten met langere vleugelgrootte



Piano et al. 2017 Global Change Biology

Stadsecologie

‘Community’ Gewogen Kenmerk Gemiddelde

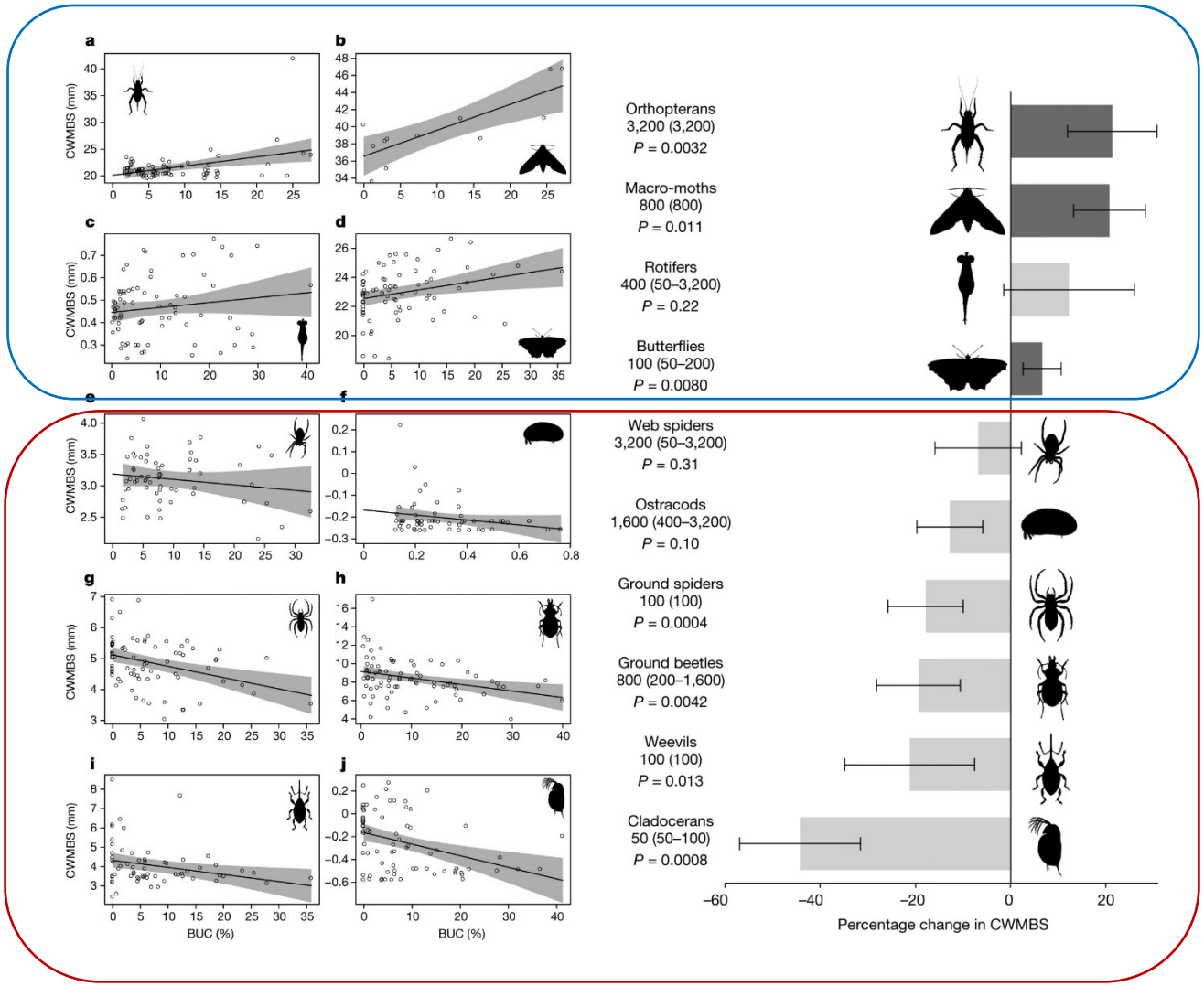
Lichaamslengte

<u>Vlinders, rechtvleugeligen, macro-motten</u>

- CWBS toename
- LL~ dispersie
- Fragmentatie

<u>Grondspinnen, snuitkevers, kevers, watervlooien</u>

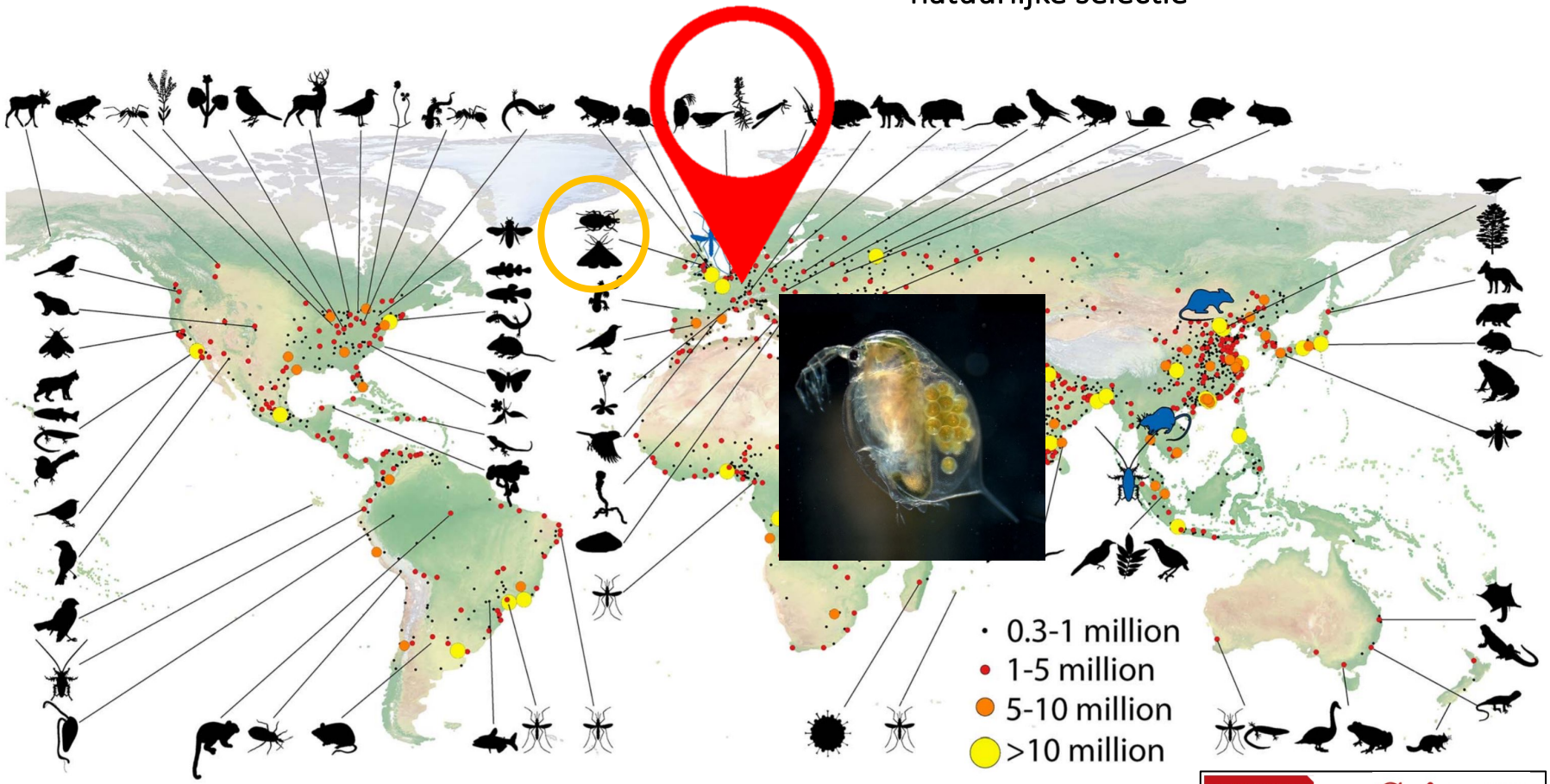
- CWBS afname
- Weinig dispersieve taxa
- UHI
- ‘krimpen’
- ‘Temperature-size rule’ (Atkinson, 1994)



Merckx et al. 2018 Nature

Evolutie in de stad?

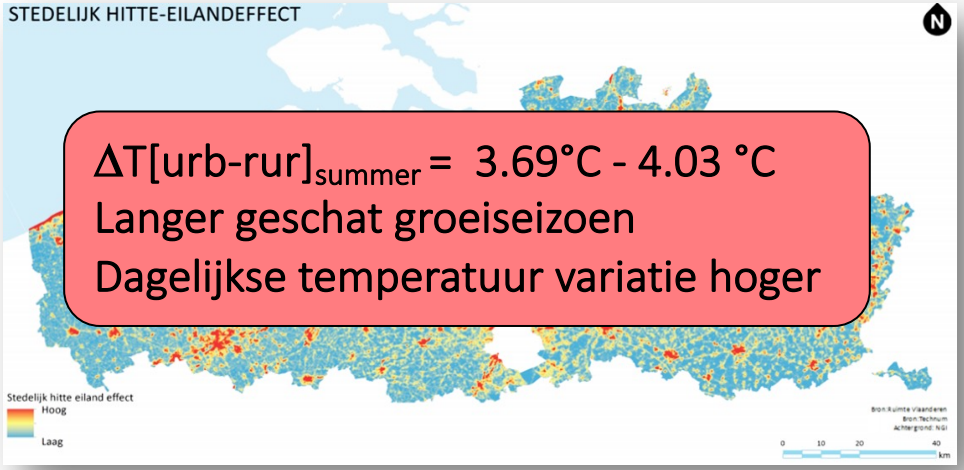
Genetische drift, gene flow, mutaties,
natuurlijke selectie



REVIEW
Science
EVOLUTION
Evolution of life in urban environments
Marc T. J. Johnson[1,2]* and Jason Munshi-South[3]*

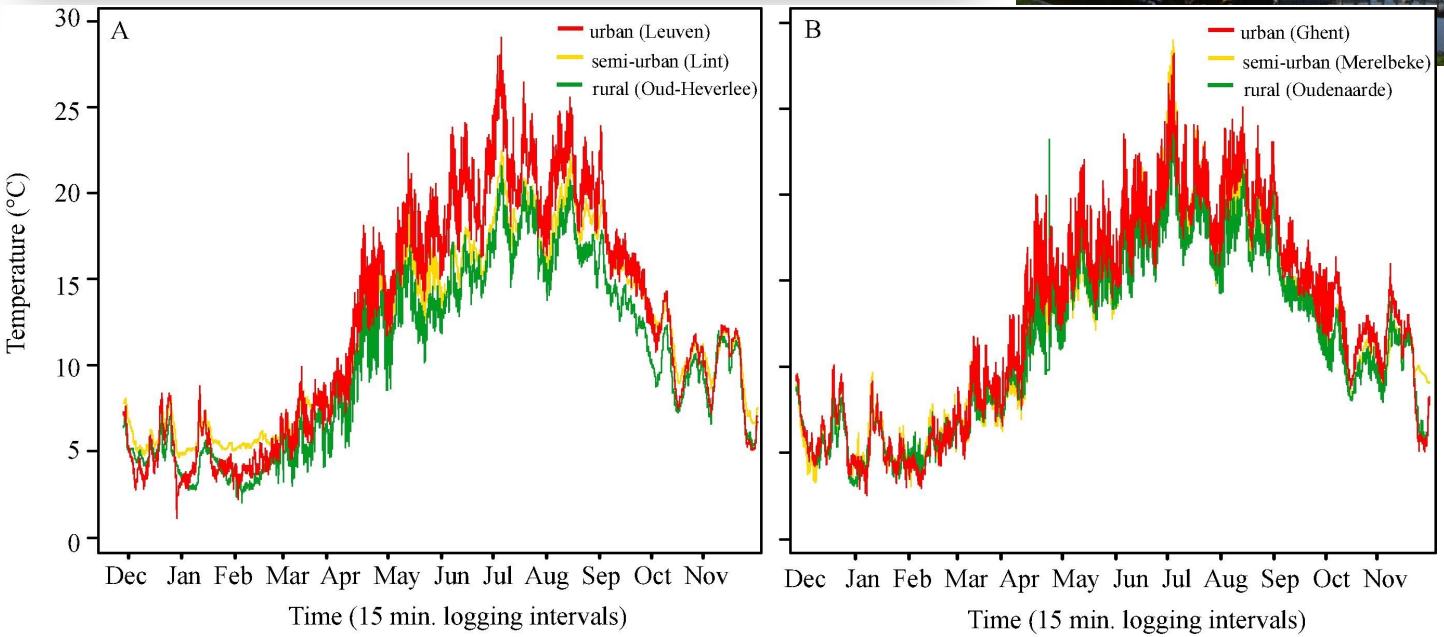
Johnson & Munshi-South 2017 Science
foto: Hajime Watanabe

De verwarming staat aan… ook in onze stadsvijvers



$\Delta T[urb\text{-}rur]_{summer}$ = 3.69°C - 4.03 °C
Langer geschat groeiseizoen
Dagelijkse temperatuur variatie hoger

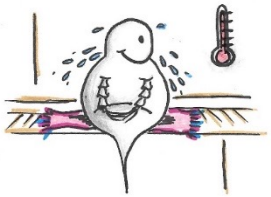
Stedelijk 'hot-tub' effect

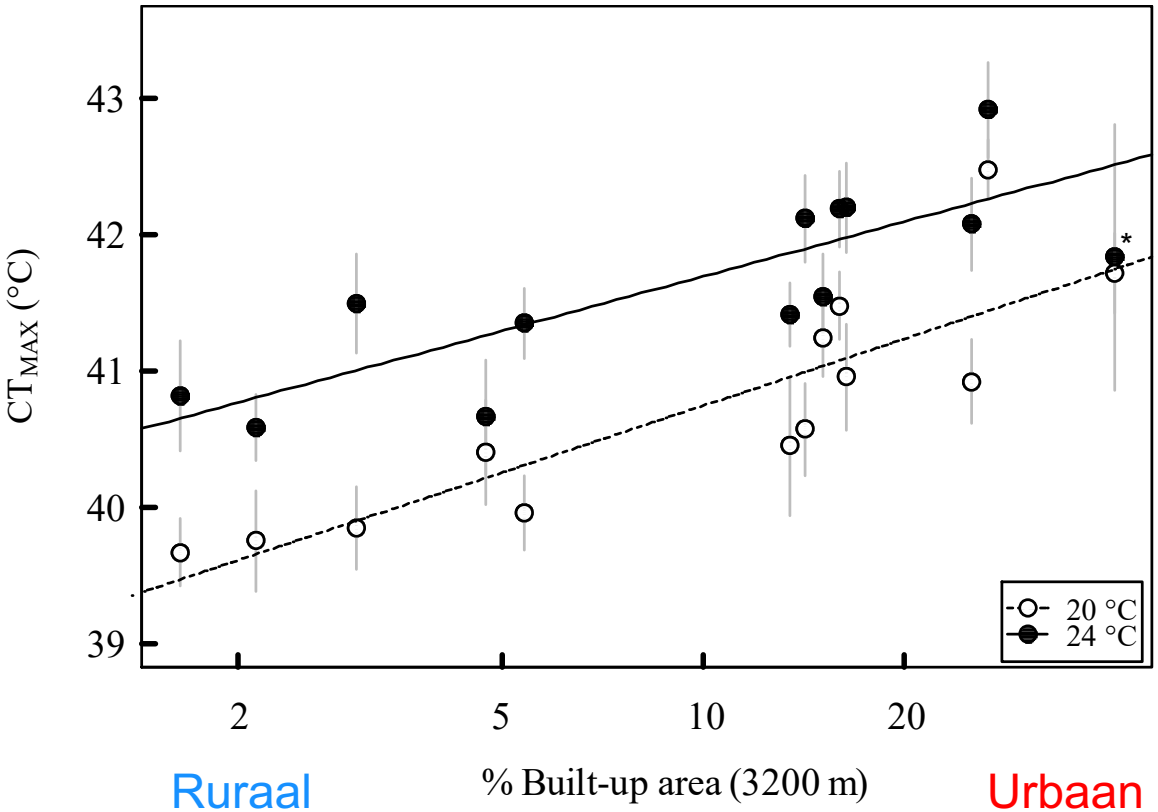


Brans et al. 2018 Landscape and Urban Planning

Resultaten (common garden)

Hittetolerantie





Ruraal — Urbaan

Percentage bebouwde oppervlakte (Built-up Area BA) als proxy voor de graad van verstedelijking

Verstedelijkingsgedreven evolutie van **hogere hittetolerantie**
ca. 2 °C! ($p < 0.001$)

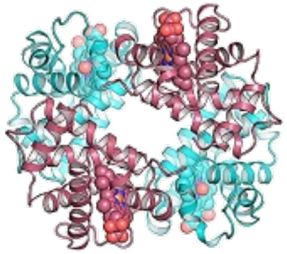
Thermale acclimatisatie:
(20 vs 24 °C)
ca. 1.25 °C ($p < 0.001$)

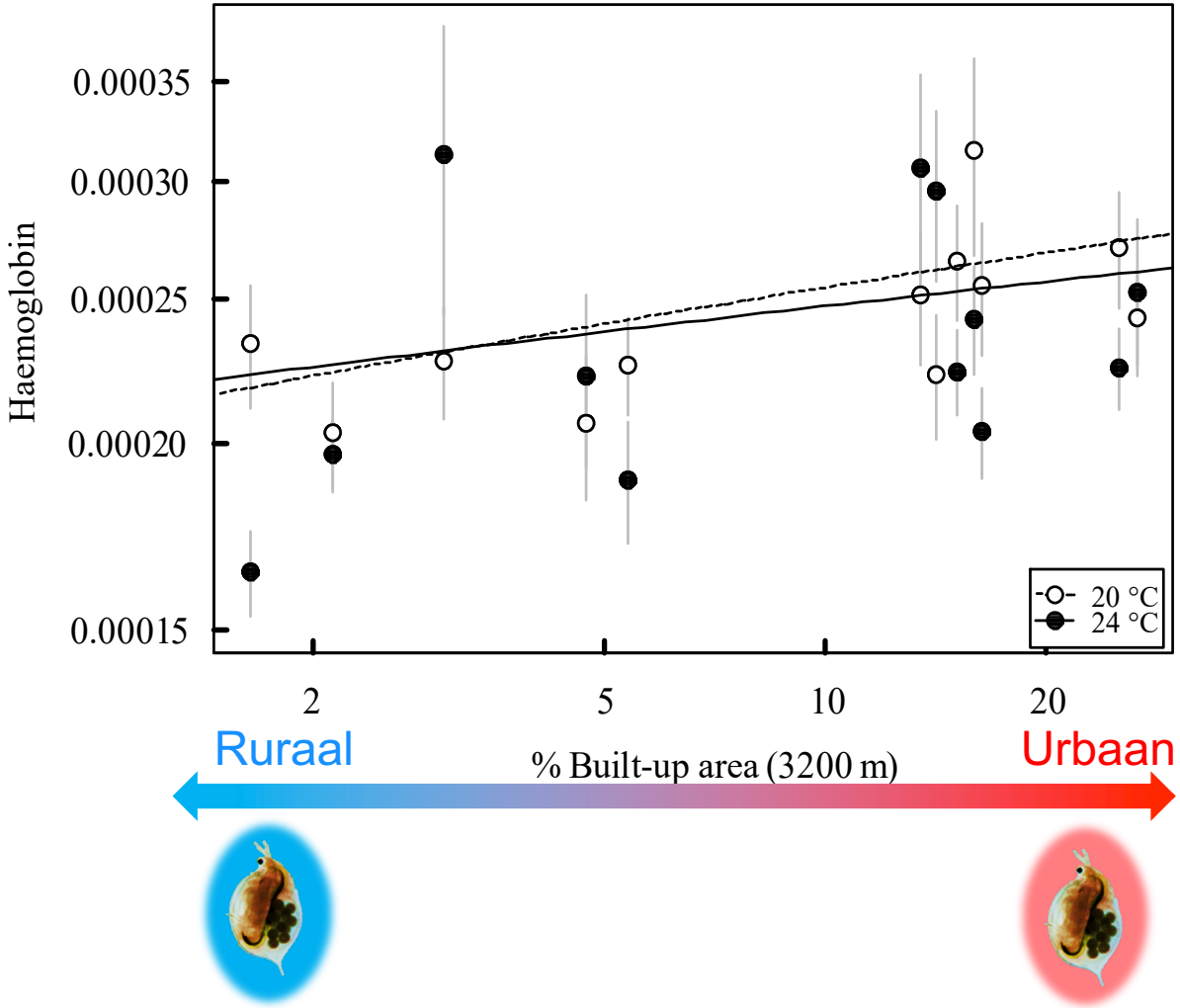
Opm.: model inclusief lichaamslengte covariaat

Acorn ants (*Themnotorax curvispinosus*)
(Diamond et al. 2018a, Proc. B, 2018b Conserv. Physiol.)

Brans et al. 2017 Global Change Biology

Hemoglobine





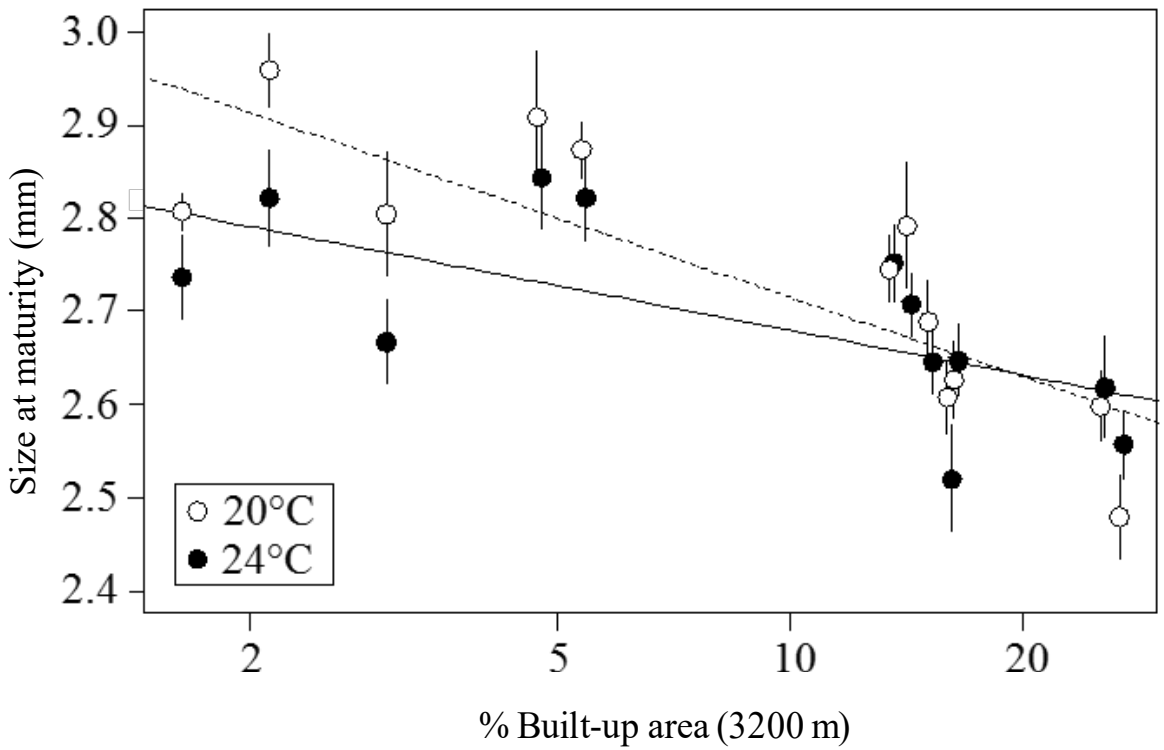
Verstedelijkingsgedreven **toename** in **hemoglobine concentraties** ($p = 0.011$)

Geen acclimatisatie (methodologisch?)

Hypoxia-tolerantie

Brans et al. 2017 Global Change Biology

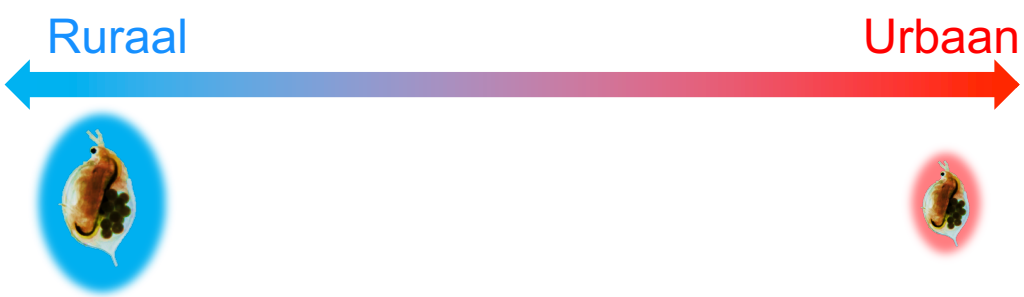
Lichaamslengte



Verstedelijkingsgedreven evolutie van een **kleinere lichaamslengte** bij maturatie (p = 0.004)

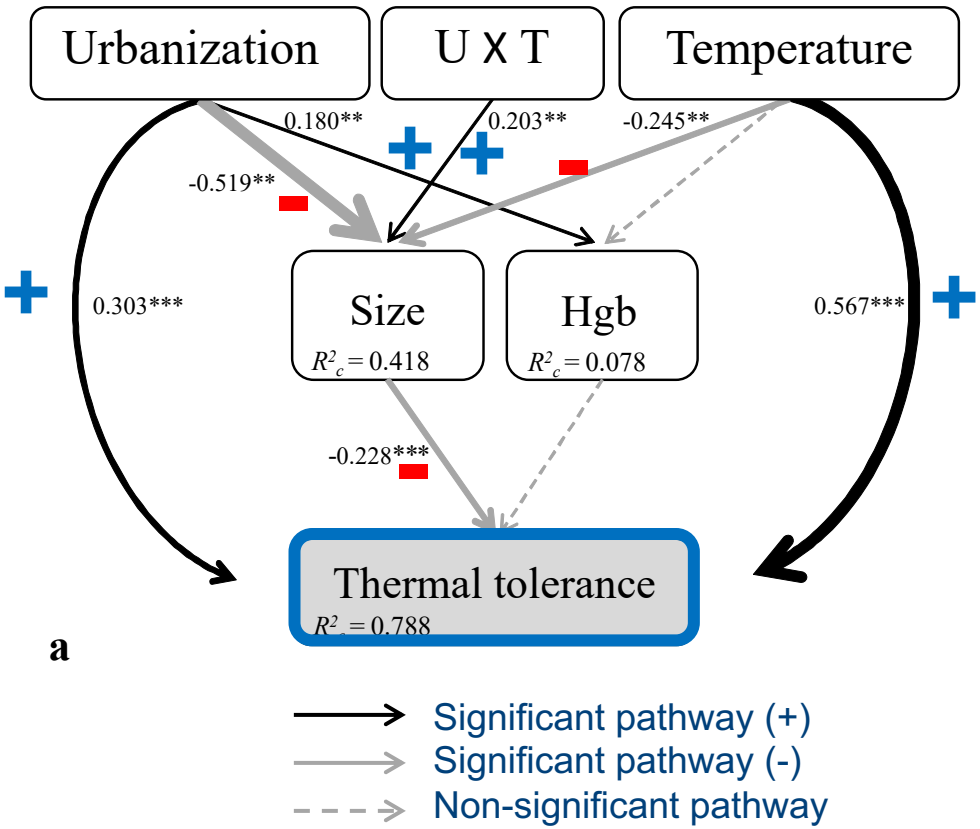
'Temperature-size rule (Atkinson, 1994)' (latitudes/altitudes/climate change)

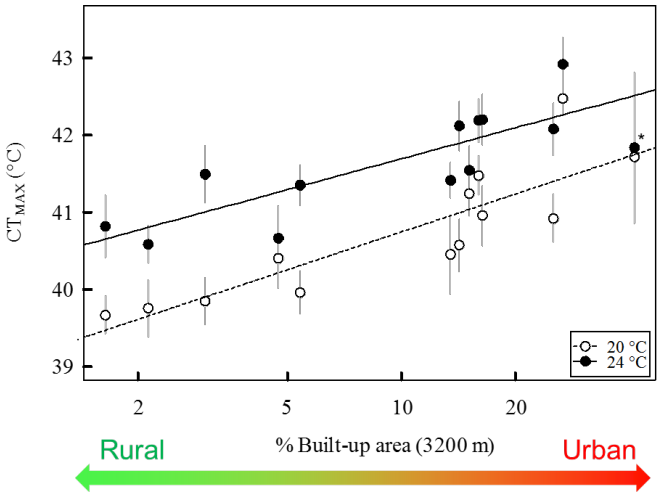
Gelijkaardig aan responsen op gemeenschapsniveau

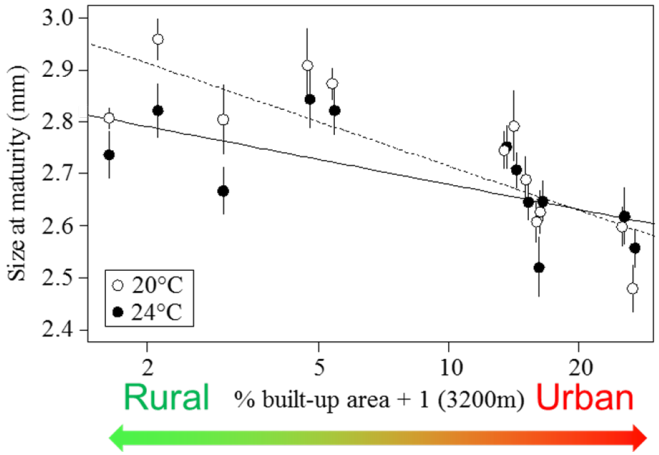


Brans et al. 2017 Philosophical Transactions B, Global Change Biology, Brans & De Meester 2018 Functional Ecology

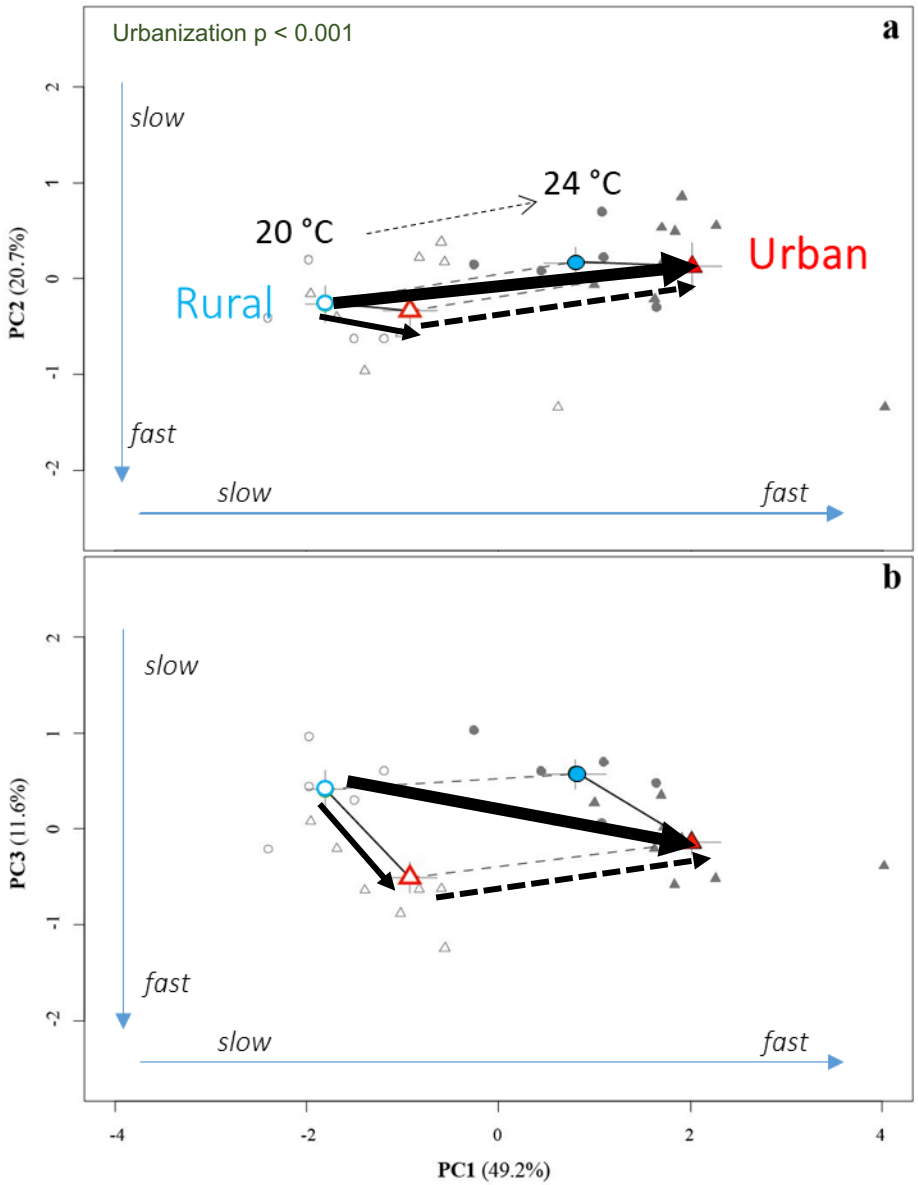
Mechanisme


Urbanization
U X T
Temperature
0.180**
0.203**
-0.245**
-0.519**
0.303***
0.567***
Size
$R^2_c = 0.418$
Hgb
$R^2_c = 0.078$
-0.228***
Thermal tolerance
$R^2_c = 0.788$
a
Significant pathway (+)
Significant pathway (-)
Non-significant pathway


CT_{MAX} (°C)
43
42
41
40
39
2
5
10
20
20 °C
24 °C
Rural
% Built-up area (3200 m)
Urban


Size at maturity (mm)
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2
5
10
20
20°C
24°C
Rural
% built-up area + 1 (3200m)
Urban

Levensritme ('pace-of-life')



Multivariate genetische differentiatie langsheen de 'traag-snel' levensritme-as ('pace-of-life'): **stadspopulaties zijn 'sneller'** (maturatie, ontwikkeling, hogere fecunditeit)

Evolutionaire respons en fenotypische plasticiteit: zelfde richting

Fenotypische Traject Analyse

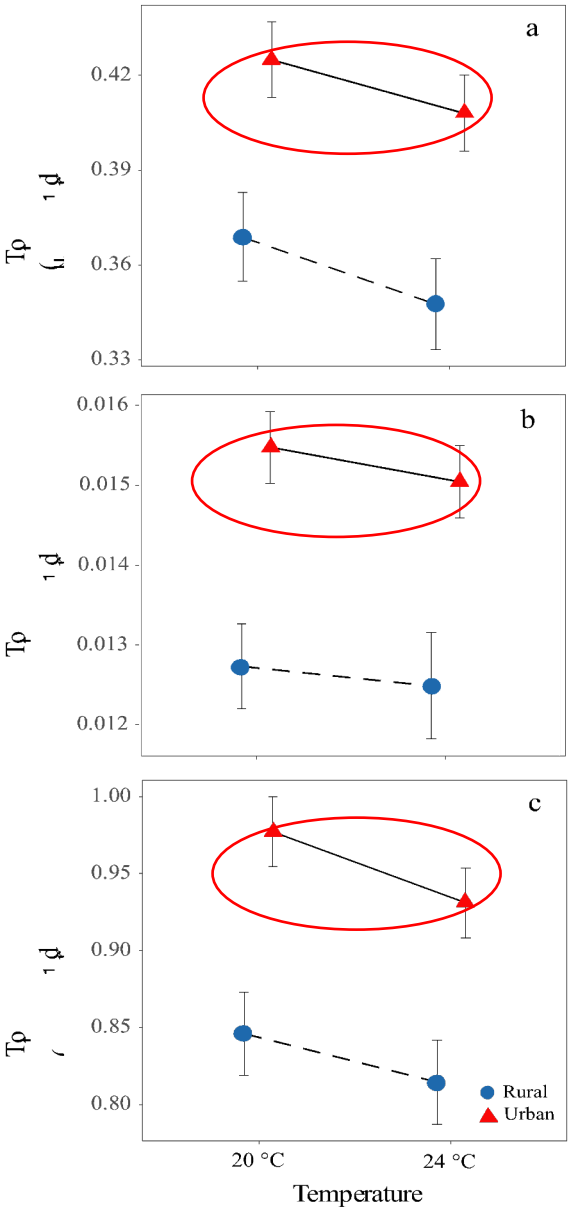
PC1: age at maturity
release of progeny
performance (*r*)
somatic growth
PC2: fecundity
PC3: size at maturity

PTA: phenotypic: 20-24 °C(dashed)
PTA: genotypic: rural-urban (full)

Brans et al. 2018 Functional Ecology

Energie

Watervlooien uit de stad verschillen genetisch in hun **energiereserves**: ze hebben hogere concentraties vet, koolhydraten, en proteïnen!



Urbanization p = 0.003

Urbanization p = < 0.001

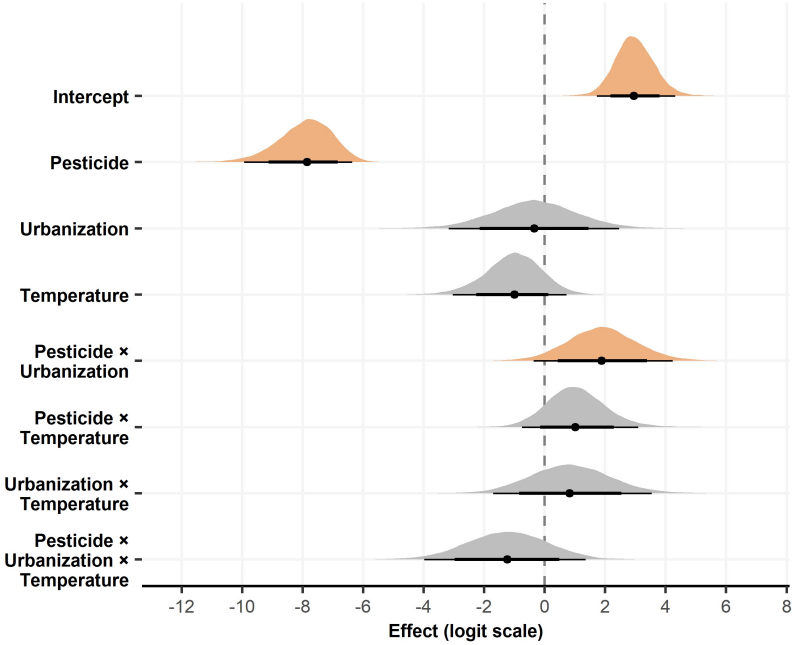
Urbanization p = 0.003
Temperature p = 0.020

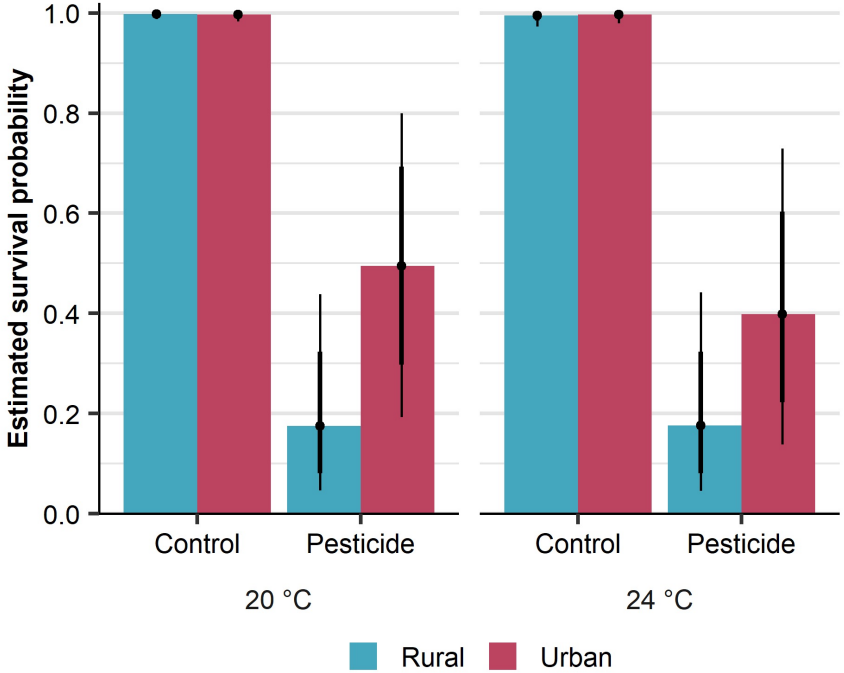
Brans et al. 2018 Proceedings B; Illustratie: Ine Swillen

Vers van de pers: pesticide resistentie

Acute toxiciteitstesten
Watervlooien uit de stad zijn **resistenter tegen het organofosfaatpesticide Chlorpyrifos (CPF 0.67 µg/L)**

Proof of principle
'cross tolerance'



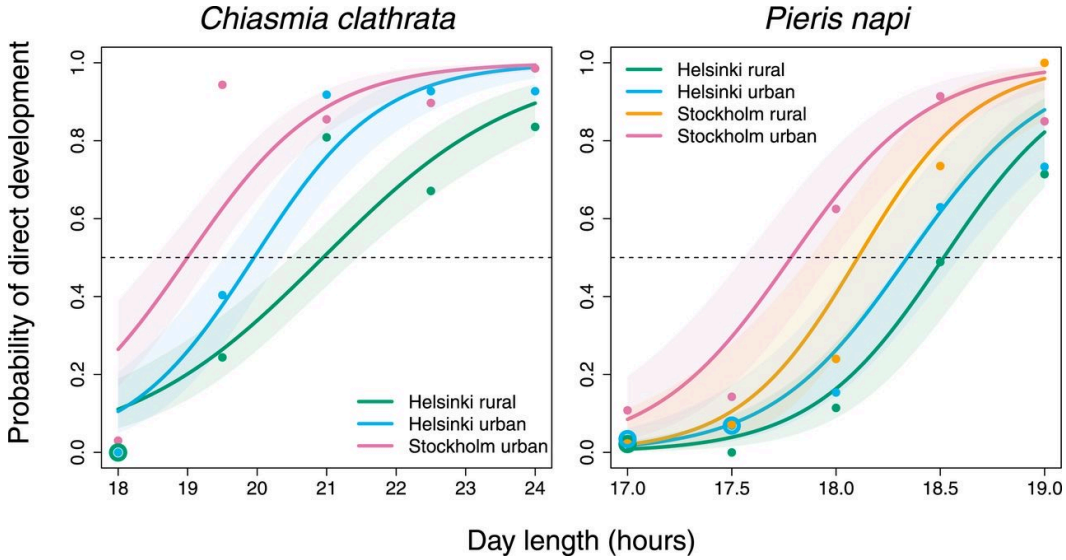


(note: Bayesian approach)

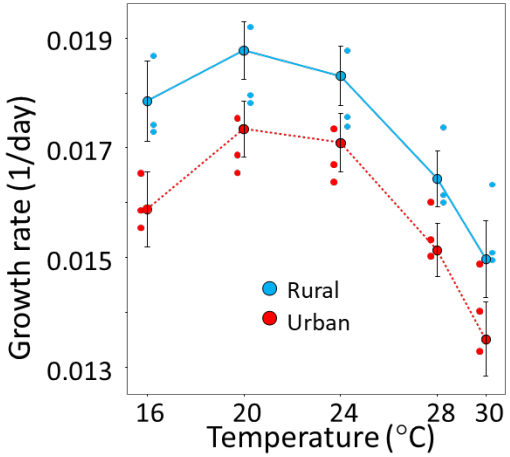
Brans, Almeida, & Fajgenblat 2021 Evolutionary Applications

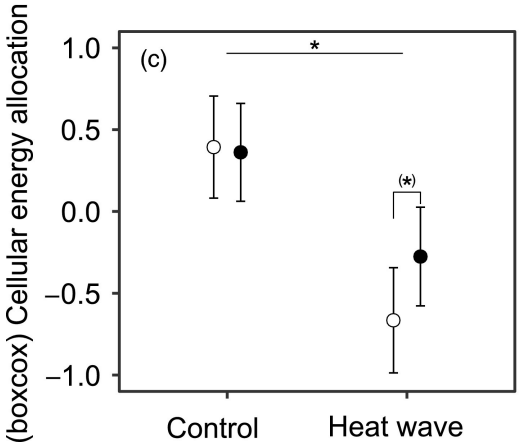
‘Urban evolution’ (in Vlaanderen) (UHI): de watervlo is niet alleen

Klaverspanner
Klein geaderd witje



Azuurwaterjuffer
Lantaarntje



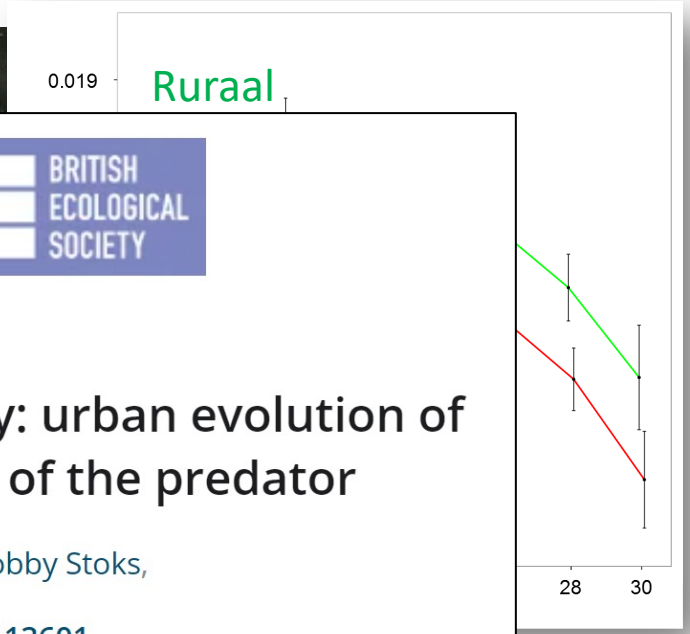


Merckx et al. 2021 PNAS
Tüzün et al. 2017 2021 Evolutionary Applications

Foto’s: Sami Kivelä, Christophe Brochard

De stadsomgeving: verder onderzoek?

Eco-evolutionaire feedbacks: predator-prooi interacties



Journal of Animal Ecology
BRITISH ECOLOGICAL SOCIETY

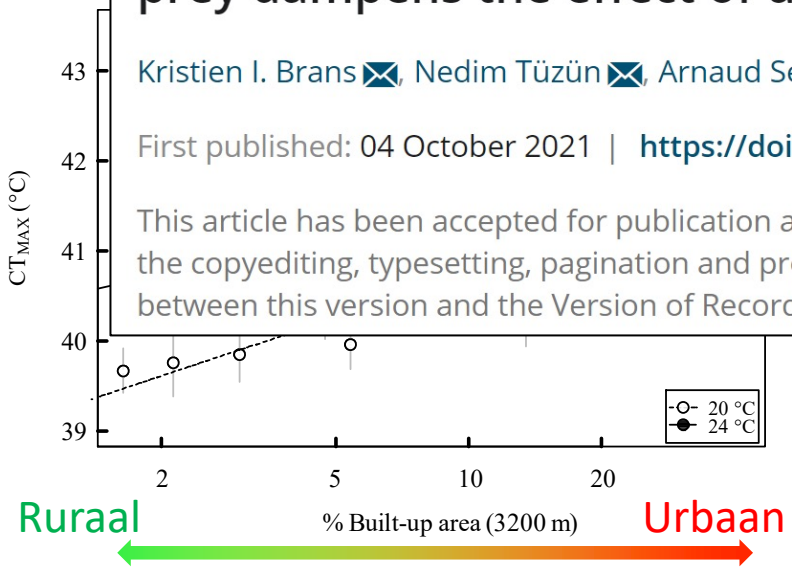
RESEARCH ARTICLE | Full Access

Cryptic eco-evolutionary feedback in the city: urban evolution of prey dampens the effect of urban evolution of the predator

Kristien I. Brans, Nedim Tüzün, Arnaud Sentis, Luc De Meester, Robby Stoks,

First published: 04 October 2021 | https://doi.org/10.1111/1365-2656.13601

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi:10.1111/1365-2656.13601



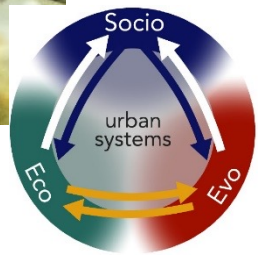
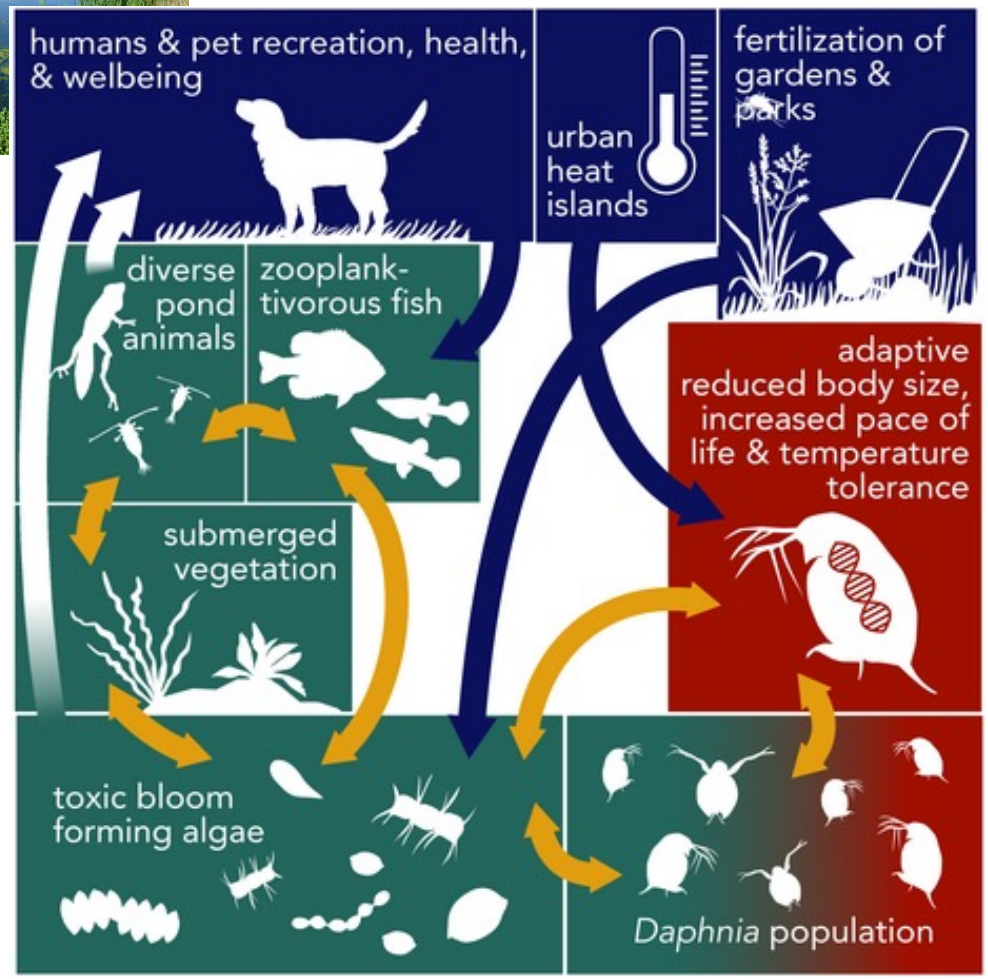


Foto: Sarah Oexle

Verwachte socio-eco-evolutionaire feedbacks



Eco-evo:

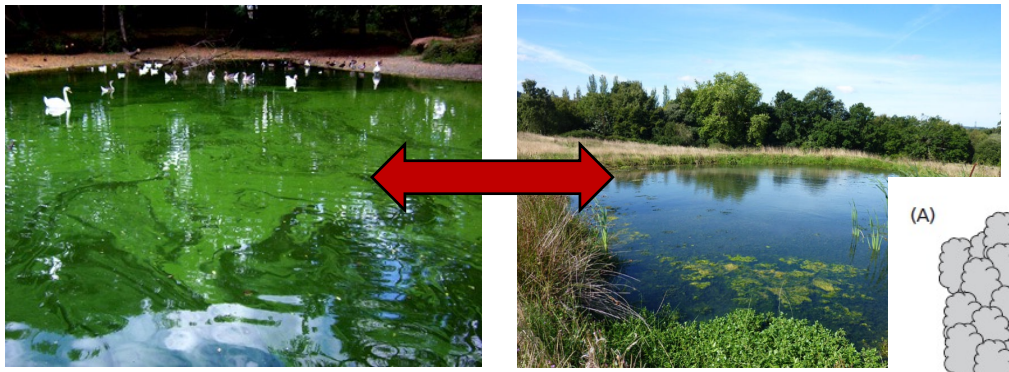
ecosysteem functies en diensten zijn potentieel **gebufferd in vergelijking met een systeem waarbij de soort zich niet kan aanpassen** en, in het geval van watervlooien, vervangen wordt door een kleinere soort

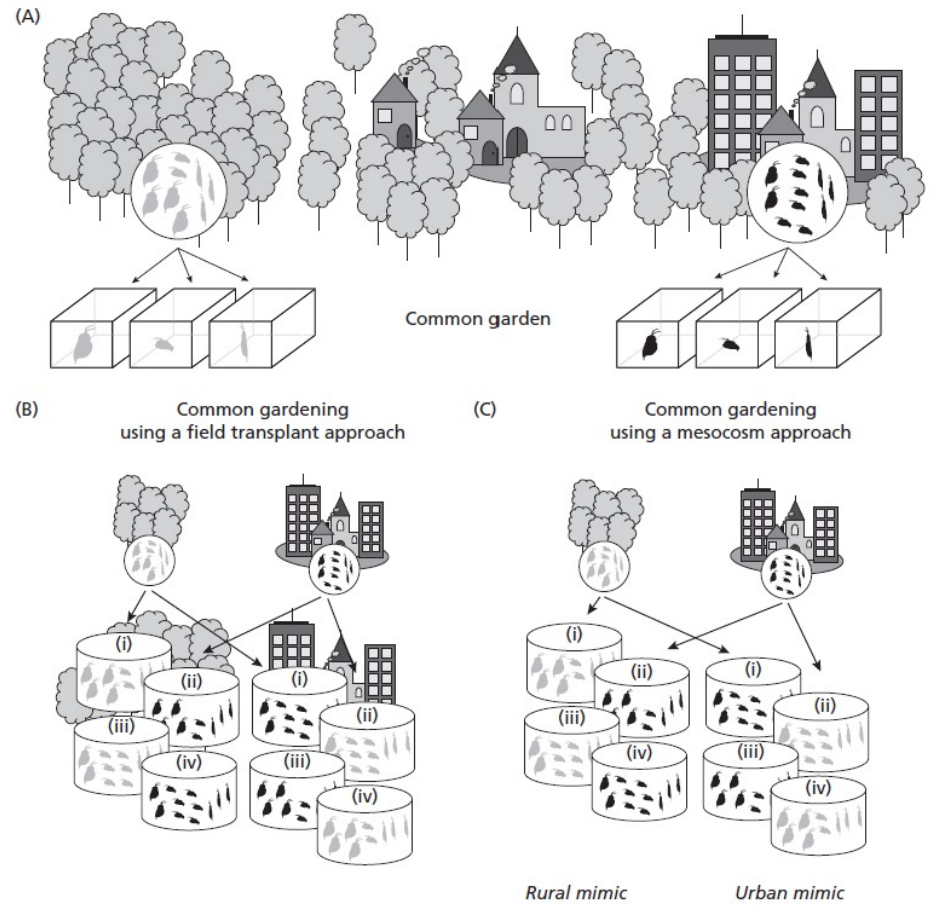
Socio:

beheer stadsvijvers aanpassen

Des Roches et al. 2020 Evolutionary Applications

Verwachte socio-eco-evolutionaire feedbacks

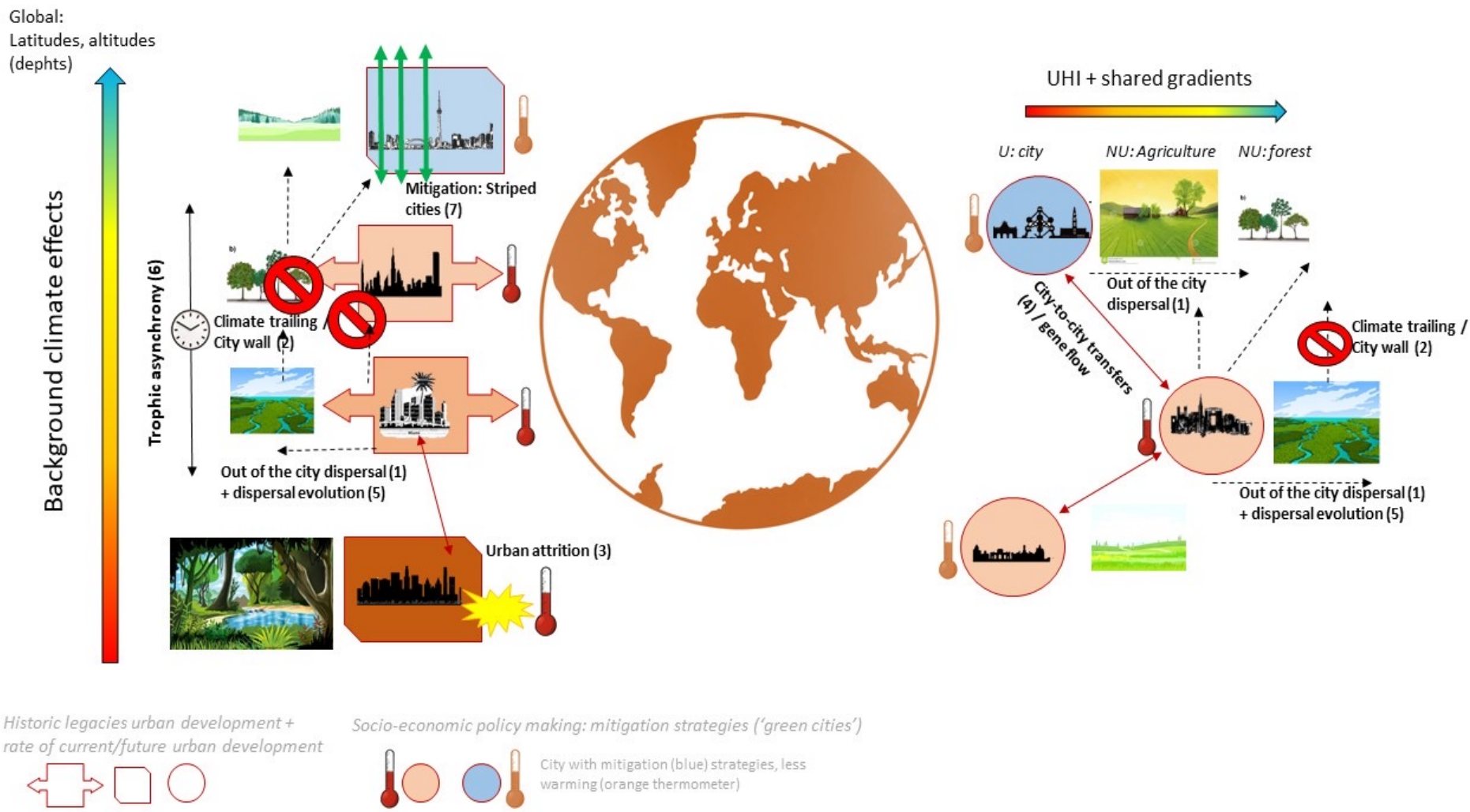




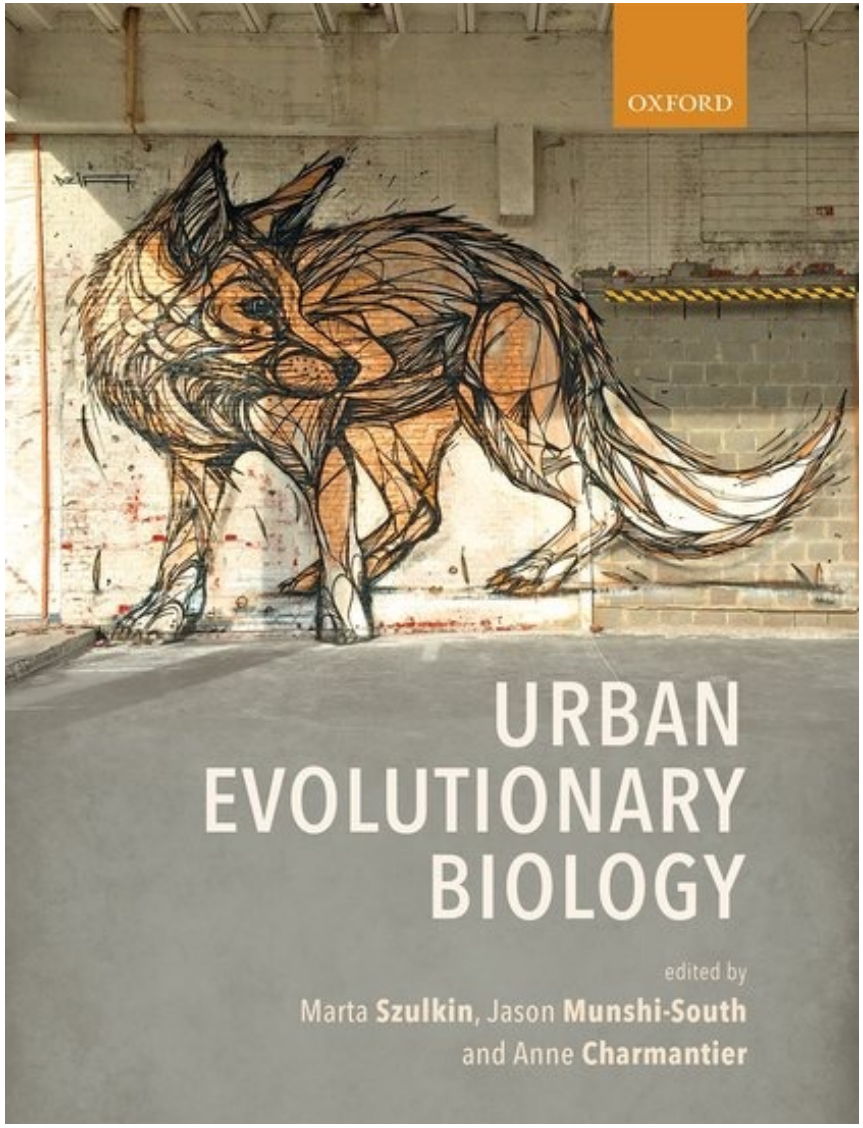
Brans, Govaert & De Meester, Chapter 11 in Urban Evolutionary Biology, Oxford UP

Transplant experimenten!

Klimaat, migratie, evolutie: integratie stadsomgeving



Boek: Urban Evolutionary Biology



"Evolutionary dynamics of metacommunities in urbanized landscapes"

Kristien I. Brans, Lynn Govaert and Luc De Meester

Oxford University Press (2020)

Bedankt!

Prof. Luc De Meester & De Meester Lab
Prof. Robby Stoks
Technical staff
SPEEDY consortium
Belspo/FWO
RCN Urban Eco-Evo Network (Prof. M. Alberti)

Ongoing research

MECHANISMS

- Gut microbiome
- Genotype specific selection of microbial taxa
- Has been shown for microcystine and AB resistance
- **Urban bacterioplankton**: metagenetics and metagenomics revealed upregulation of pathways in BP associated with **metabolization of** drugs, antibiotics, pesticides and other chemicals *(Mukherjee et al., in prep)*

SOCIO-ECO-EVO

- Grazing and top-down control of algae
- Tranpslant anno 2021-2022 (pray for me)!