Arctic Biodiversity Congress; October 2018 in Rovaniemi, Finland; Session KNO10: Arctic terrestrial invertebrate diversity

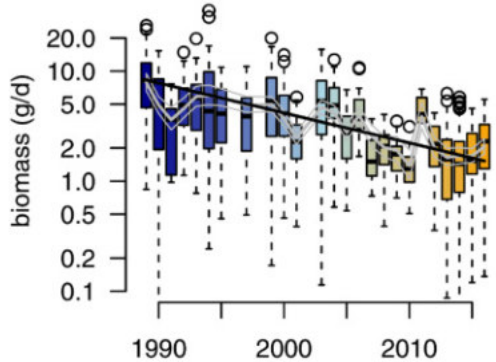
Mapping Constraints of Climate and Land-Type on Insect Compositions

Douglas Chesters[1], Philip Beckschäfer[2,3], Sarah J. Adamowicz[4], Michael C. Orr[1], Chao-Dong Zhu[1], Kwok-Pan Chun[5]

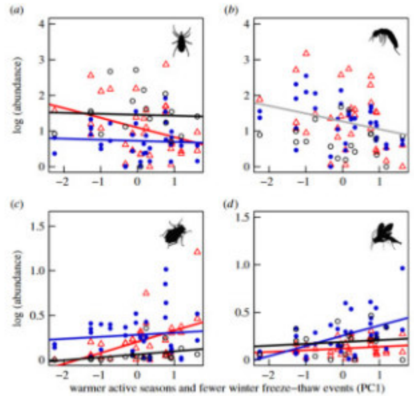
1 Key Laboratory of Zoological Systematics and Evolution, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China.
2 Forest Inventory and Remote Sensing, Faculty of Forest Sciences and Forest Ecology, Göttingen University, 37077 Göttingen, Germany.
3 Northwest German Forest Research Station, 37079 Göttingen, Germany.
4 Biodiversity Institute of Ontario & Department of Integrative Biology, University of Guelph, Ontario, Canada
5 Department of Geography, Hong Kong Baptist University, Baptist University Road, Kowloon Tong, Hong Kong Special Administrative Region of China.

Elucidating climate and land type drivers of insects has to deal with very little long term data for insects

- 25 years of Malaise trapping in natural reserves of Germany. 75% decline in insect biomass (Hallman et al. 2017)



- Since 1996, climatic and arthropod monitoring at Zackenberg research station, east Greenland (Koltz et al. 2018)



Studies of climate on insect composition usually taxon-limited

Table 2. Altitudinal trends in abundance for selected insect species, excluding host-specific parasitoids and predators

Species	Order	Host plant	Locality	Altitudinal trend	Reference
Strophingia ericae	Hemiptera	*Calluna vulgaris*	UK	None	Hodkinson *et al.* (1999)
Strophingia cinereae	Hemiptera	*Erica cinerea*	UK	Decreasing	Hodkinson *et al.* (1999)
Yponomeuta mahalebella	Lepidoptera	*Prunus mahleb*	Spain	Decreasing	Alonso (1999)
Ditropis pteridis	Diptera	*Pteridium aquilinum*	UK	Decreasing at four sites	Lawton *et al.* (1987)
Chirosia parvicornis	Diptera	*Pteridium aquilinum*	UK	Decreasing at two out of three sites, none at remainder	Lawton *et al.* (1987)
Dasineura filicina	Diptera	*Pteridium aquilinum*	UK	Decreasing at one out of four sites, none at remainder	Lawton *et al.* (1987)
Dasineura pteridicola	Diptera	*Pteridium aquilinum*	UK	Decreasing at one out of three sites, none at remainder	Lawton *et al.* (1987)
Strongylogaster lineata	Hymenoptera	*Pteridium aquilinum*	UK	None	Lawton *et al.* (1987)
Tephritis arnicae	Diptera	*Arnica montana*	Germany	Increasing	Scheidel *et al.* (2003)
Acyrthosiphon brivicorne	Homoptera	*Dryas octopetala*	Sweden	Increasing	Strathdee *et al.* (1995)
Galerucella griscescens	Coleoptera	*Sanguisorba tenuifolia*	Japan	Decreasing	Suzuki (1998)
Kaltenbachia strobi	Diptera	*Picea abies*	Switzerland	Increasing	Wermelinger *et al.* (1995)
Torymus sp.	Hymenoptera	*Picea abies*	Switzerland	Increasing	Wermelinger *et al.* (1995)
Cydia strobilella	Lepidoptera	*Picea abies*	Switzerland	Decreasing	Wermelinger *et al.* (1995)
Leptocarabus procerulus	Coleoptera	Predator	Japan	Decreasing	Sota (1996)
Leptocarabus arboreus	Coleoptera	Predator	Japan	Increasing	Sota (1996)
Cacopsylla palmeni	Homoptera	*Salix lapponum*	Norway	Decreasing	Hill & Hodkinson (1995)
Cacopsylla brunneipennis	Homoptera	*Salix lapponum*	Norway	Decreasing	Hill & Hodkinson (1995)
Neodiprion sertifer	Hymenoptera	*Pinus sylvestris*	Finland	Increasing	Niemelä *et al.* (1987)
Dactynotus sp.	Homoptera	*Solidago macrophylla*	USA	Decreasing	Kelly (1998)
Campiiglossa albiceps	Diptera	*Solidago macrophylla*	USA	None	Kelly (1998)
Aphid	Homoptera	*Polemonium viscosum*	USA	Decreasing	Galen (1990)
Lymantria monacha	Lepidoptera	*Pinus abies*	Italy	Decreasing	Cescatti & Battisti (1992)
Drosophila (12 spp.)	Diptera		Japan	Decreasing	Ichijô *et al.* (1982)
Drosophila (six spp.)	Diptera		Japan	None	Ichijô *et al.* (1982)
Drosophila makinoi	Diptera		Japan	Increasing	Ichijô *et al.* (1982)
Nuculaspis tsugae	Homoptera	*Tsuga* spp.	Japan	None	McClure (1985)

Hodkinson 2005

nature climate change

LETTERS

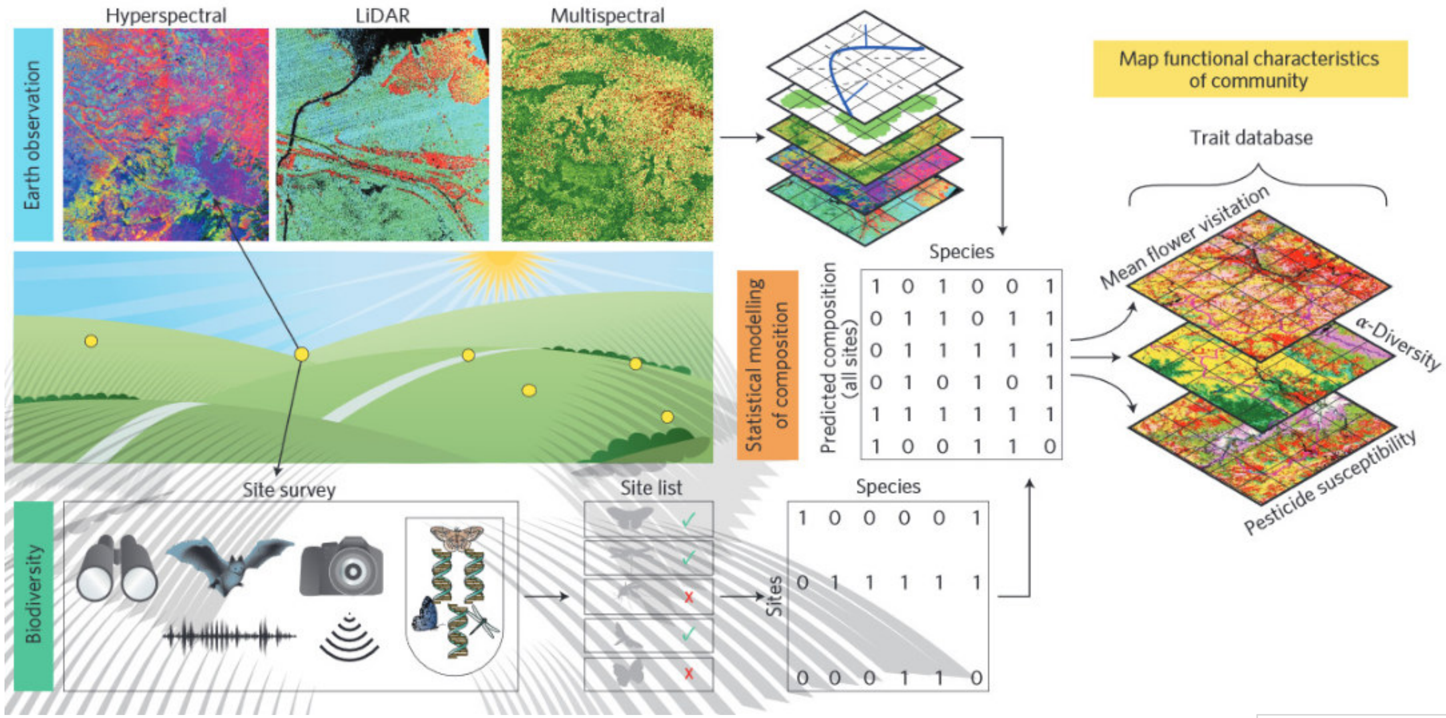
PUBLISHED ONLINE: 10 JANUARY 2012 | DOI: 10.1038/NCLIMATE1329

Continent-wide response of mountain vegetation to climate change

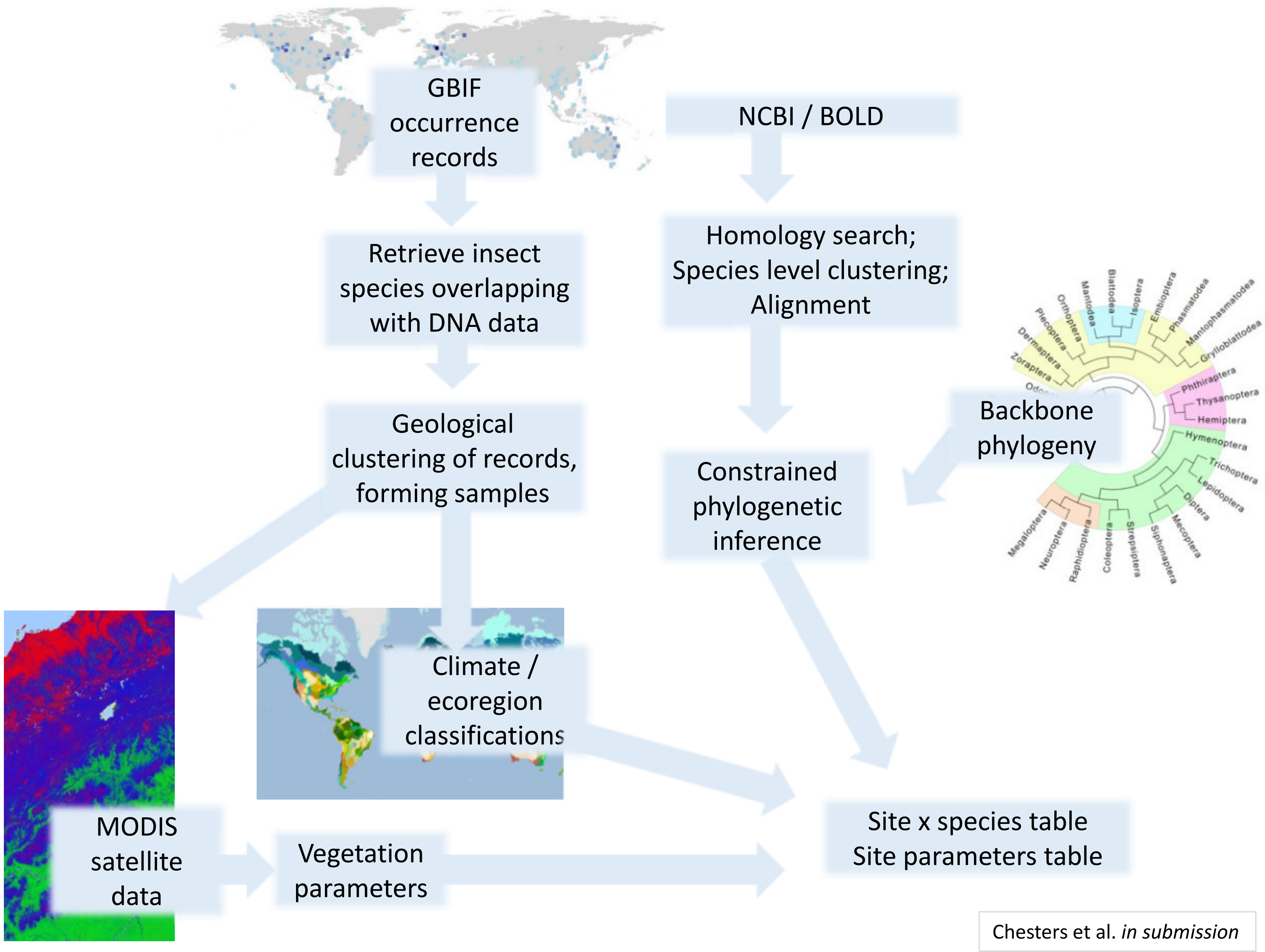
Michael Gottfried[1], Harald Pauli[2*], Andreas Futschik[3], Maia Akhalkatsi[4], Peter Barančok[5],

- at continental scale, cold-adapted species decline and the more warm-adapted species increase
- ‘at the scale of individual mountains this general trend may not be apparent'

The goal:
Real-time understanding of community composition and functions

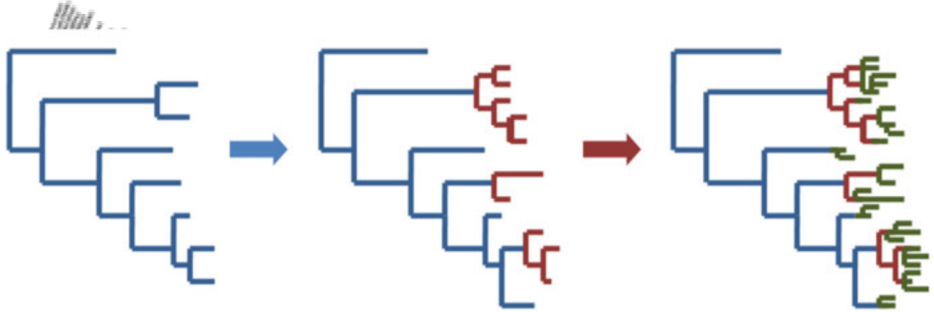


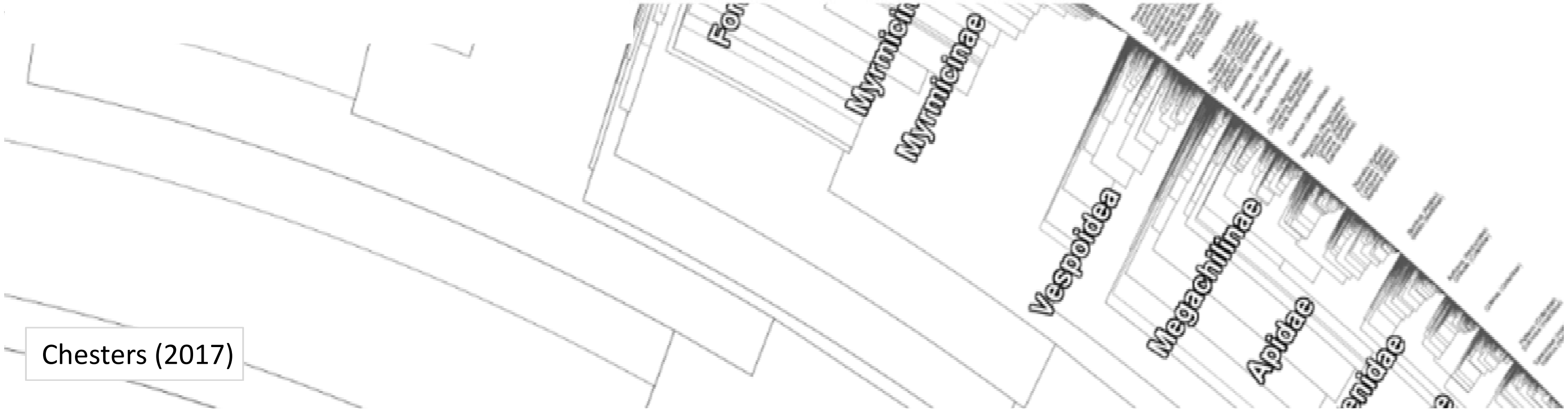
Bush et al. (2017)


GBIF occurrence records
NCBI / BOLD
Retrieve insect species overlapping with DNA data
Homology search; Species level clustering; Alignment
Geological clustering of records, forming samples
Constrained phylogenetic inference
Backbone phylogeny
Blattodea
Isoptera
Mantodea
Orthoptera
Plecoptera
Dermaptera
Zoraptera
Embioptera
Phasmatodea
Mantophasmatodea
Grylloblattodea
Phthiraptera
Thysanoptera
Hemiptera
Hymenoptera
Trichoptera
Lepidoptera
Diptera
Mecoptera
Siphonaptera
Strepsiptera
Coleoptera
Raphidioptera
Neuroptera
Megaloptera
Climate / ecoregion classifications
MODIS satellite data
Vegetation parameters
Site x species table
Site parameters table
Chesters et al. *in submission*

DNA Barcodes to Species-Level Phylogeny

- Backbone constraints enable high quality phylogenies from barcode data



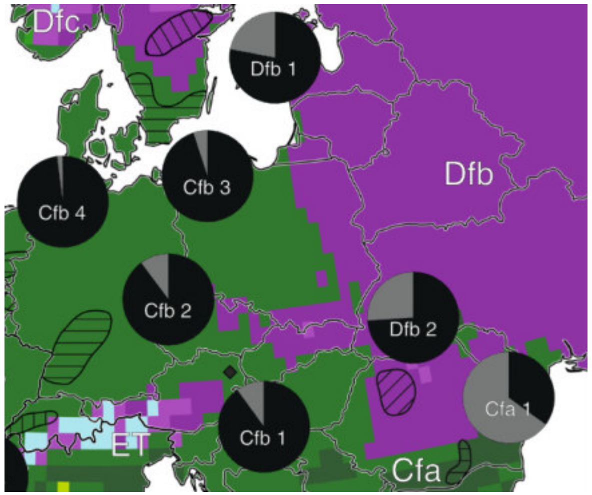


Chesters (2017)

From GBIF to environmental classification: climate

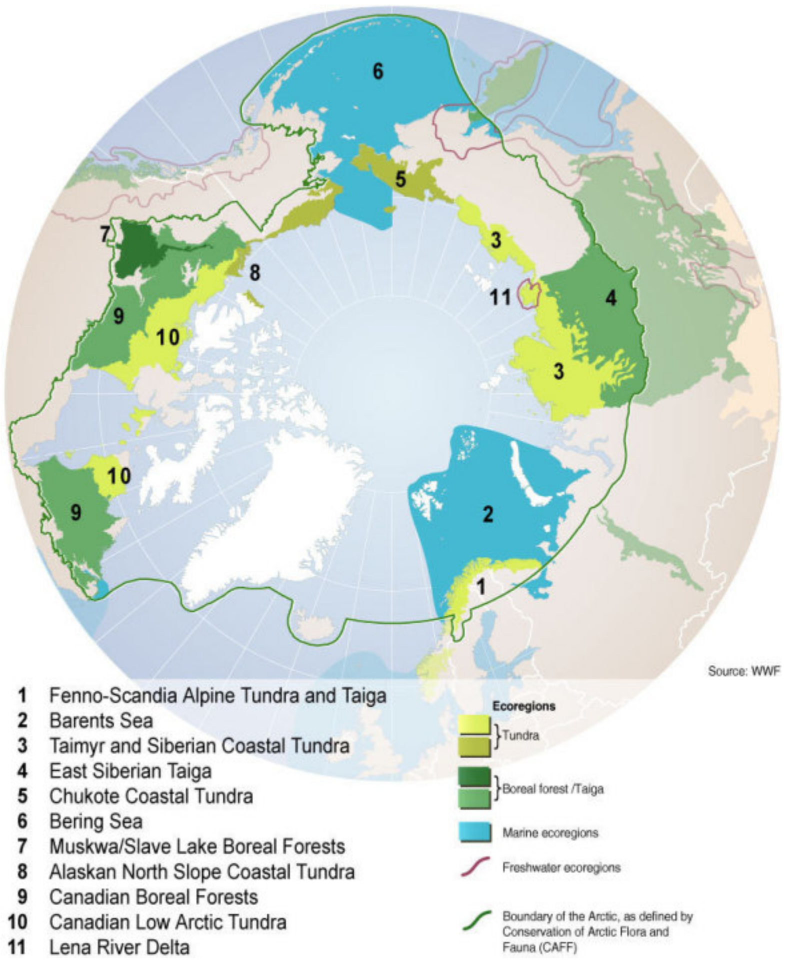
- Climate classification using the Köppen-Geiger climate system
- Kottek et al. (2006) is the most popular system, based on explicit rules of temperature and precipitation conditions
- Limited data, although in some cases KG boundaries shared with insect species

```
D   Cold
 s   - dry summer
 w   - dry winter
 f   - w/o dry season
E   Polar
 F   - frost
 T   - tundra
```



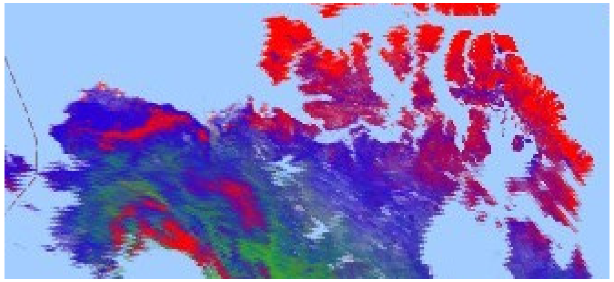
From GBIF to environmental classification: ecoregion

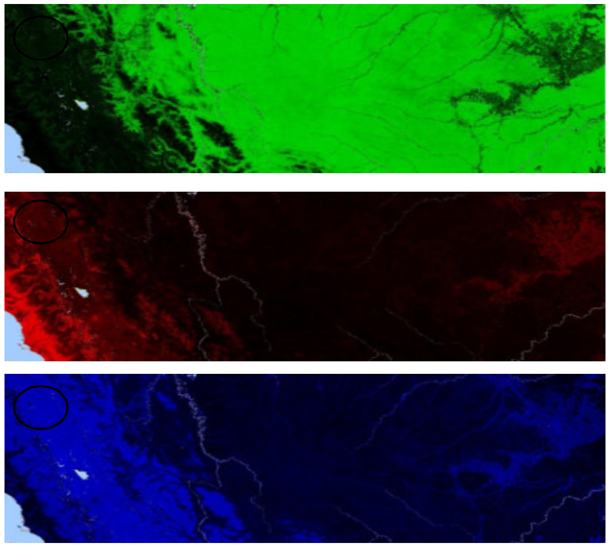
- Terrestrial ecoregions (Olson et al. 2001)
- Use extensive expert knowledge and existing regional maps
- 3 levels
  - Ecoregion
  - Realm
  - Biome



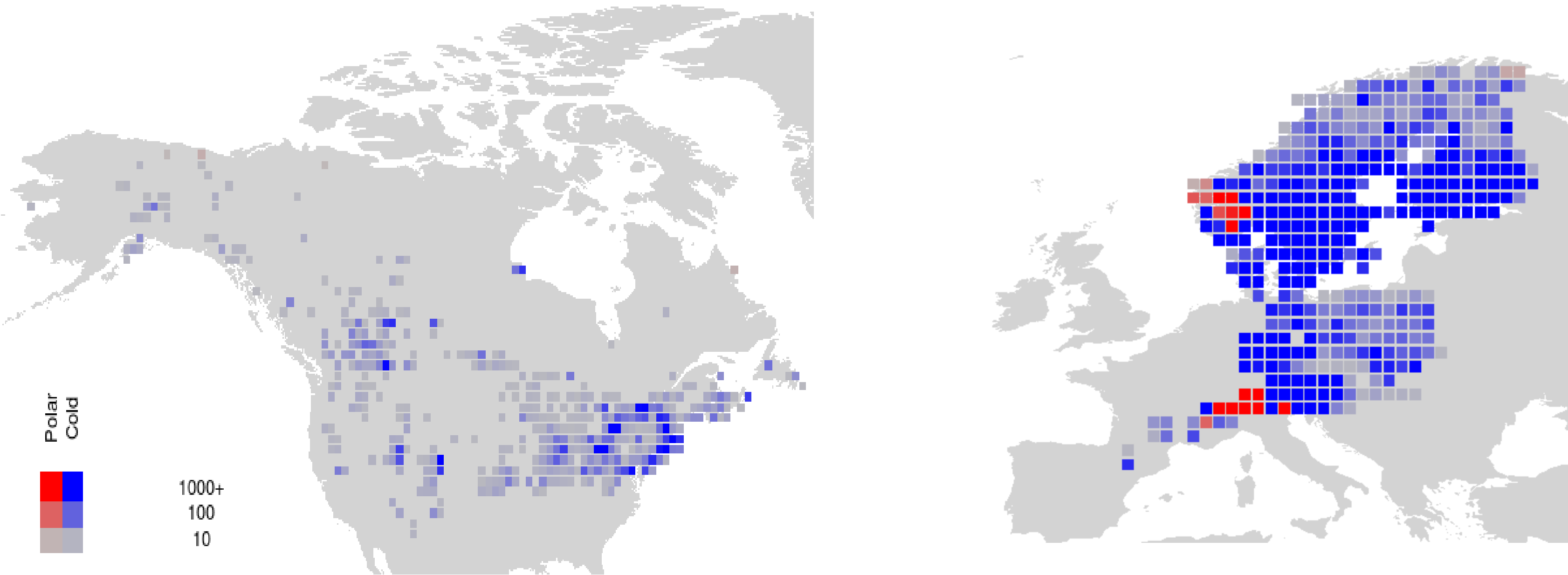
From GBIF to environmental classification: RS Vegetation analysis

- Vegetation Continuous Fields (VCF) product generated using monthly composites of MODIS 250 and 500 meters Land Surface Reflectance data
- Gives annual global estimates of vegetation cover
  - tree vegetation
  - herbaceous vegetation
  - bare ground percentages



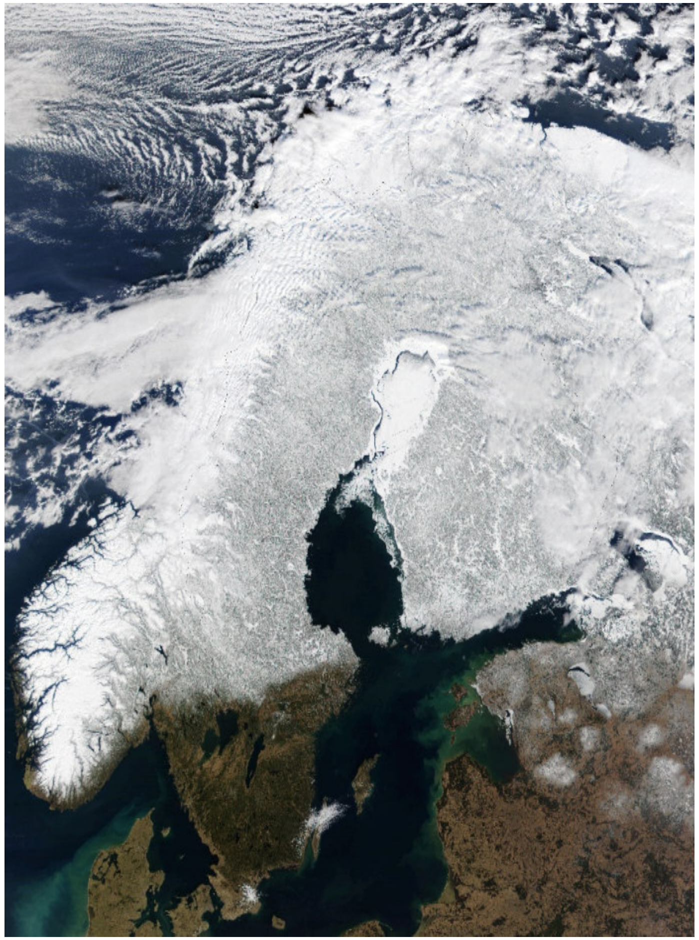


GBIF occurrences for Cold and Polar climates

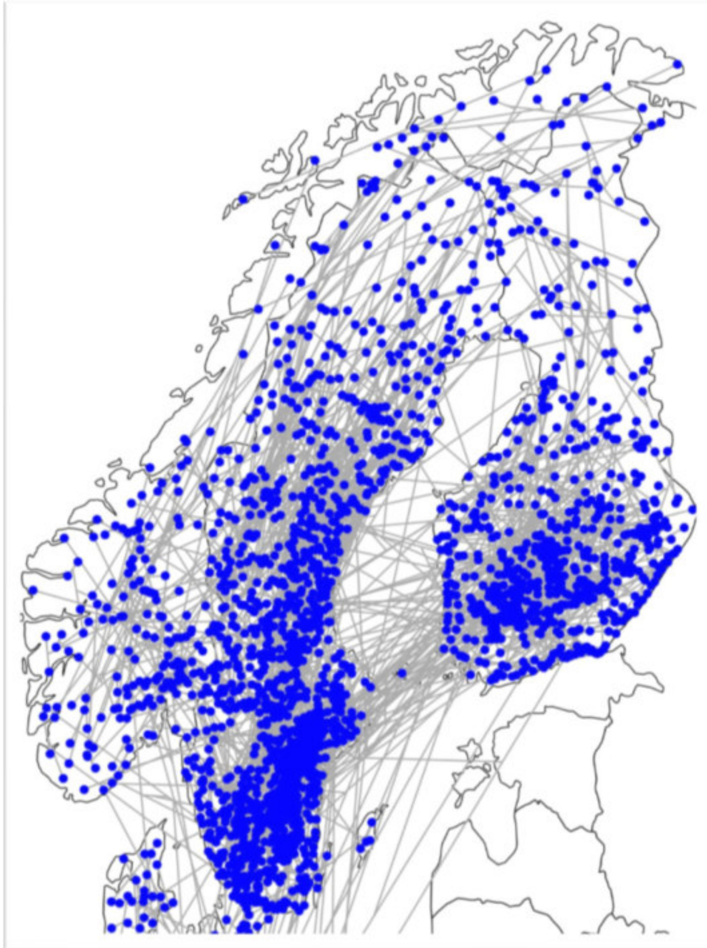


Analysis in brief

- Geographic observation grouped into sample sites
- Compositional dissimilarities between sites calculated with non-metric multidimensional scaling
- Based on compositional distances, site hierarchically clustered
- Fitting of environmental variables (vectors) or classes (factors) onto ordination via maximum correlation
- Dissimilarities separated to species and phylogenetic components
- Phylogenetic diversity indices calculated

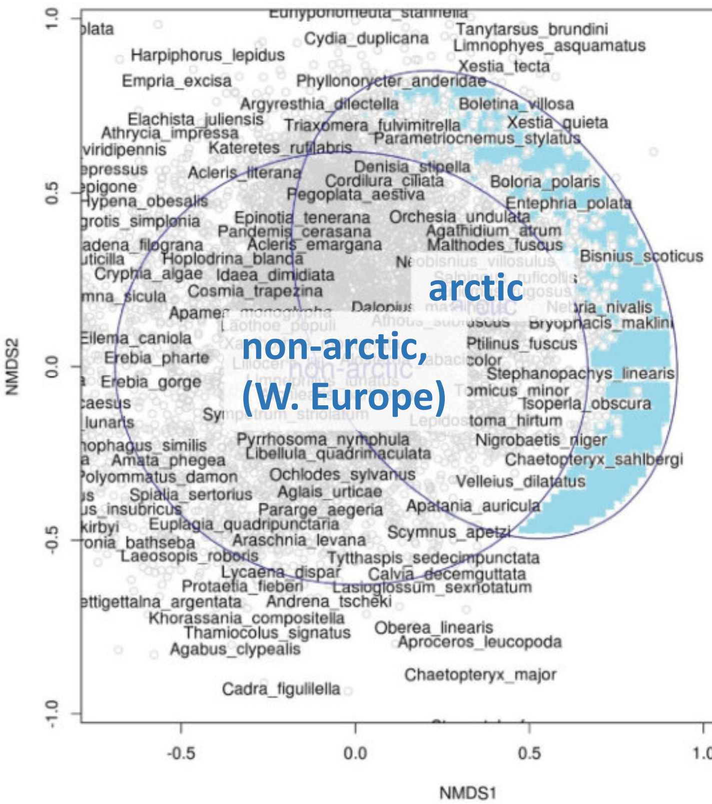


Descloitres et al. MODIS Team, NASA.



Chesters et al. *in submission*

Whistle-stop tour of Insects in the Fennoscandian Arctic

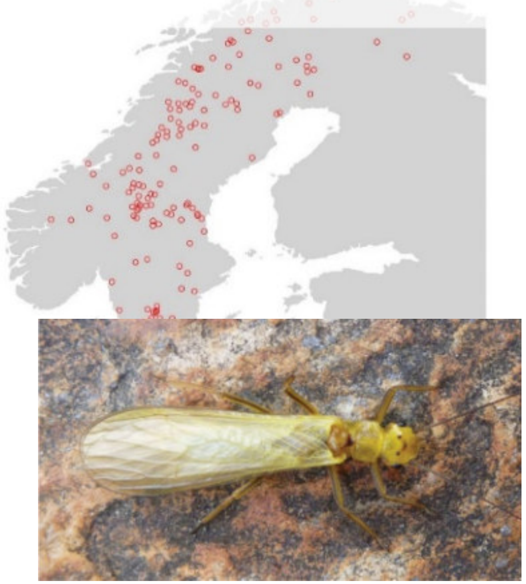


- *Bolaria polaris* (Polaris fritillary)
    - Butterfly with high arctic distribution, habitat fell heath

V. Kononenko

- *Entephria polata*
    - Geometrid moth of high arctic

- Stonefly *Isoperla obscura*
- In Fennoscandia, found at high altitudes and latitudes.
- Very sensitive to temperature regimes



Isoperla sp. from W. Graf et al.

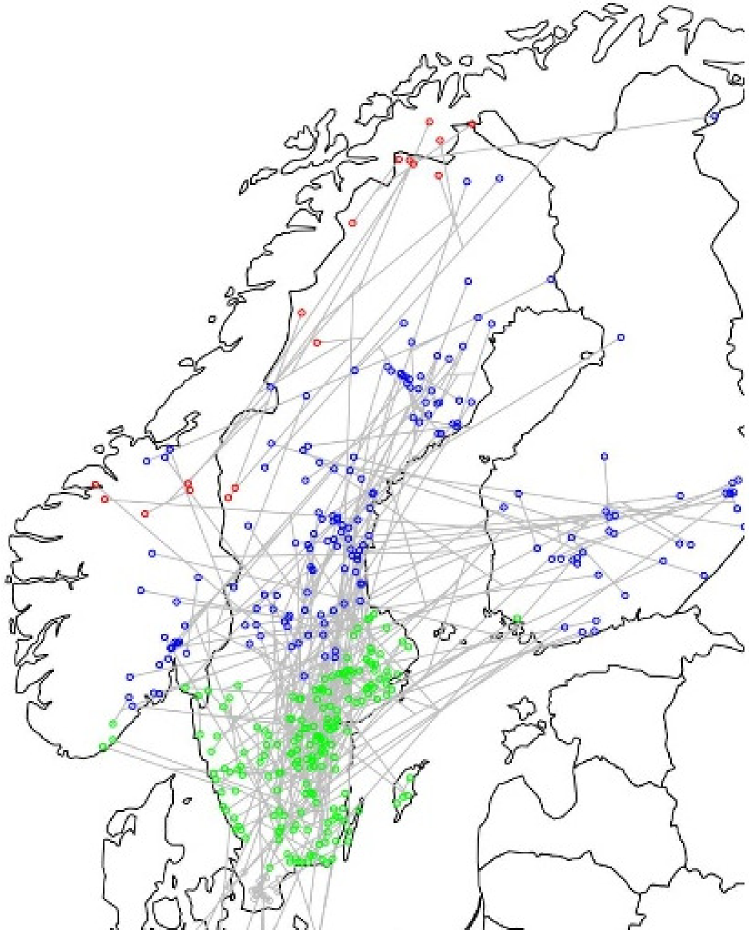
- Polar bumblebee, one of the most common bumblebees in the arctic
- Has a congeneric parasite

Alpinobombus. A. Staverløkk


Chironomidae
Agromyzidae
Sciaridae
Chironomidae
Chironomidae
Cantharidae
Noctuidae
Sciaridae
Tenebrionidae
Hippoboscidae
Endomychidae
Elachistidae
Tortricidae
Halictidae
Pyralidae
Staphylinidae
Staphylinidae
Languriidae
Chironomidae
Staphylinidae
Ciidae
Syrphidae
Staphylinidae
Crambidae
Crambidae
Noctuidae
Tipulidae
Formicidae
Apidae
Geometridae
Noctuidae
Crambidae
Staphylinidae
Staphylinidae
Sisyridae
Staphylinidae
Staphylinidae
Staphylinidae
Leiodidae
Staphylinidae
Syrphidae
Staphylinidae
Staphylinidae
Staphylinidae
Noctuidae
Staphylinidae
Staphylinidae
Cantharidae
Carabidae
Ceratopogonidae
Chironomidae
Capniidae
Staphylinidae
Melandryidae
Leiodidae
Melandryidae
Ptiliidae
Cantharidae
Hydrophilidae
Ptiliidae
Nitidulidae
Ptinidae
Salpingidae
Latridiidae
arctic
Leiodidae
Elateridae
Erotylidae
Elateridae
Elateridae
Nitidulidae
Carabidae
Elateridae
Zygaenidae
Anobiidae
Cerambycidae

Compositional Dissimilarity : Rove Beetles (Staphylinidae)

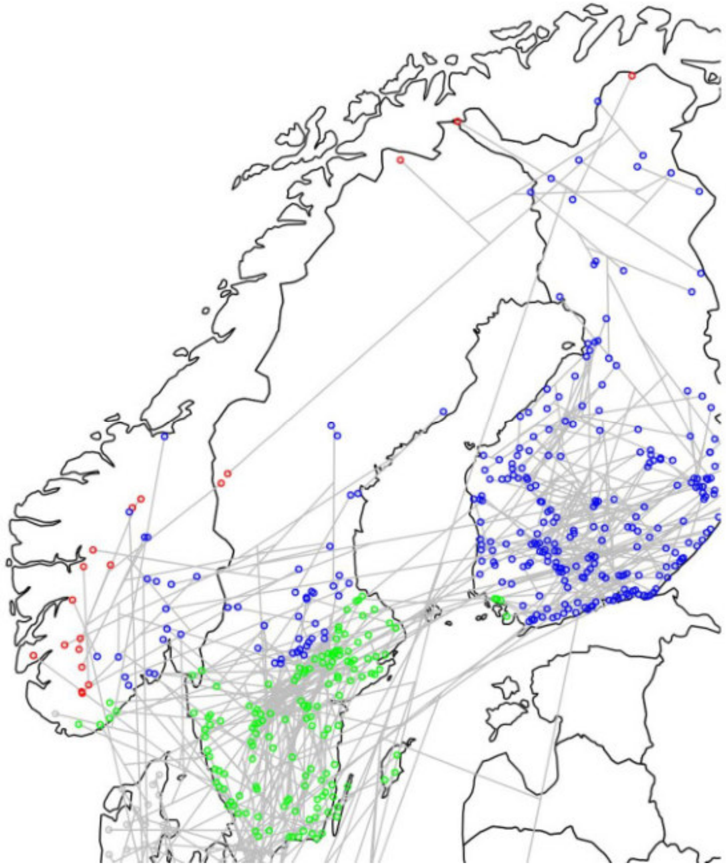
	Tree Cover	Non Tree Vegetation	Latitude	Climate	Ecoregion
Carabids	0.0125 (0.001)	0.0123 (0.001)	0.0074 (0.001)	0.0147 (0.001)	0.1005 (0.001)
Staphylinids	**0.0609 (0.001)**	**0.0613 (0.001)**	**0.0768 (0.001)**	**0.0180 (0.002)**	**0.1219 (0.001)**
Tortricidae	0.0307 (0.001)	0.0213 (0.001)	0.0604 (0.001)	0.0146 (0.001)	0.0763 (0.001)
Noctuidae	0.0188 (0.001)	0.0205 (0.001)	0.0125 (0.001)	0.0217 (0.001)	0.1465 (0.001)



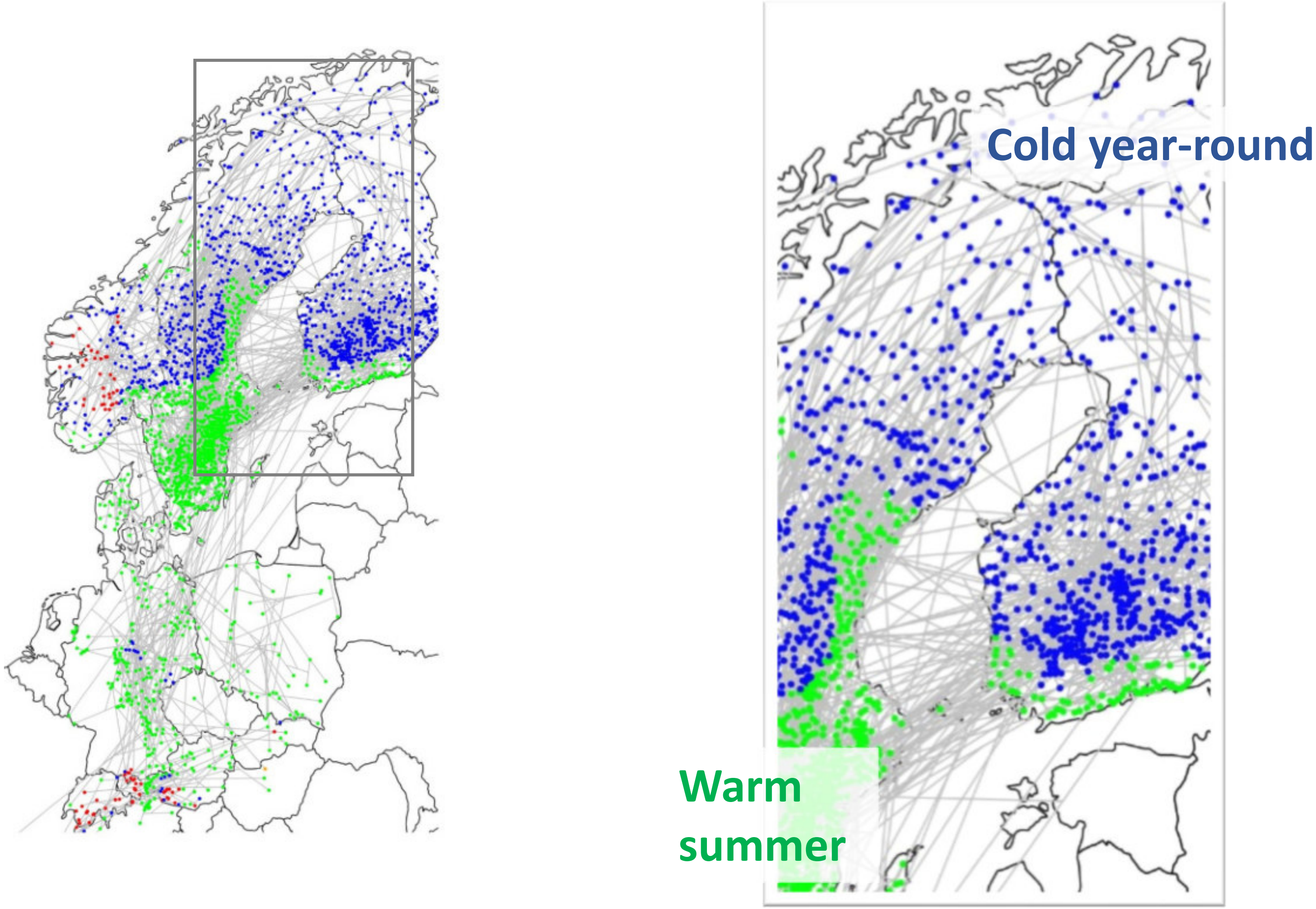
Ecoregion:
Blue =Taiga
Green = Sarmatic mixed forests
Red = Montane Birch Forest + grassland

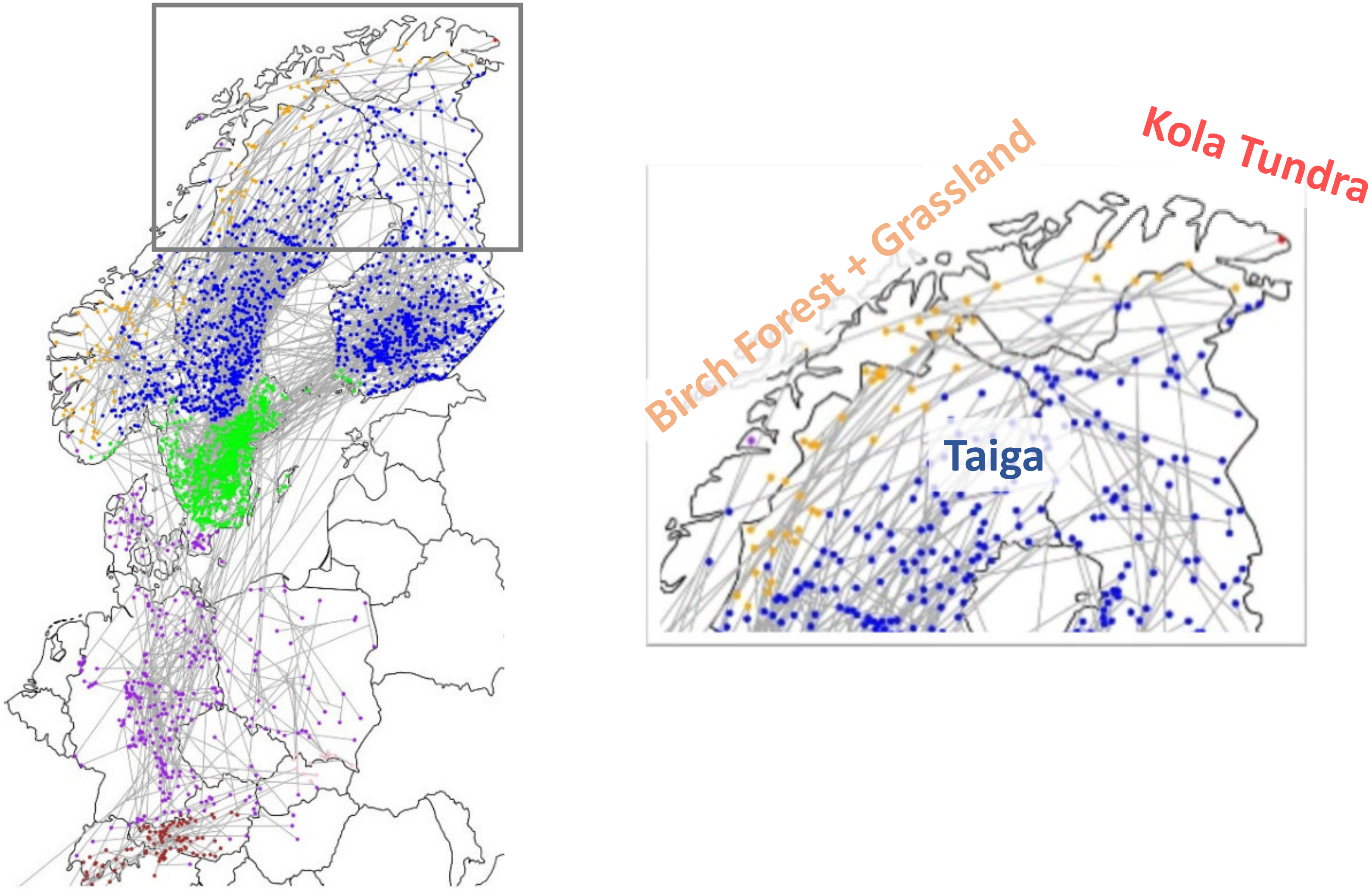
Compositional Dissimilarity : Owlet Moths (Noctuidae)

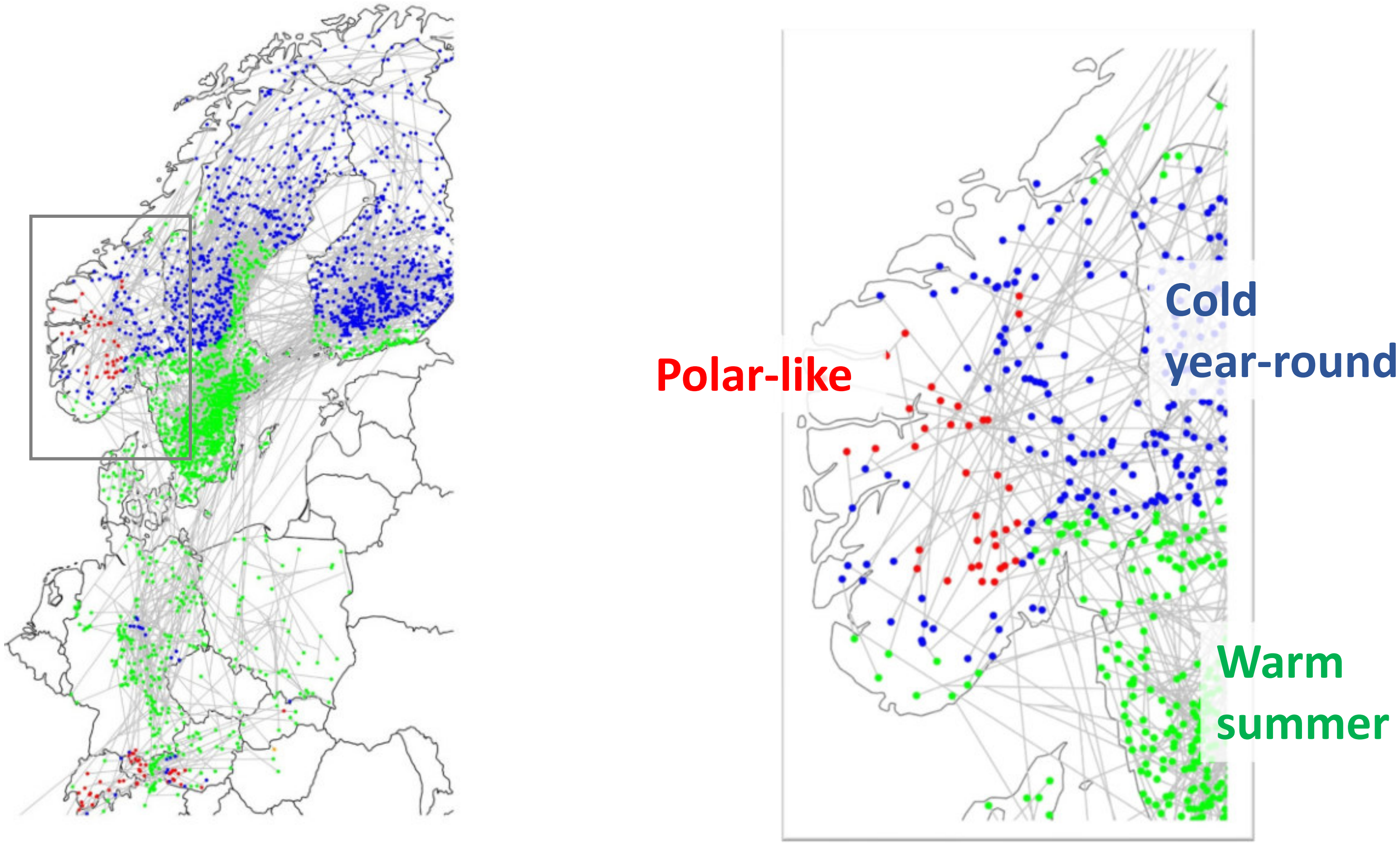
	Tree Cover	Non Tree Vegetation	Latitude	Climate	Ecoregion
Carabids	0.0125 (0.001)	0.0123 (0.001)	0.0074 (0.001)	0.0147 (0.001)	0.1005 (0.001)
Staphylinids	0.0609 (0.001)	0.0613 (0.001)	0.0768 (0.001)	0.0180 (0.002)	0.1219 (0.001)
Tortricidae	0.0307 (0.001)	0.0213 (0.001)	0.0604 (0.001)	0.0146 (0.001)	0.0763 (0.001)
Noctuidae	**0.0188 (0.001)**	**0.0205 (0.001)**	**0.0125 (0.001)**	**0.0217 (0.001)**	**0.1465 (0.001)**

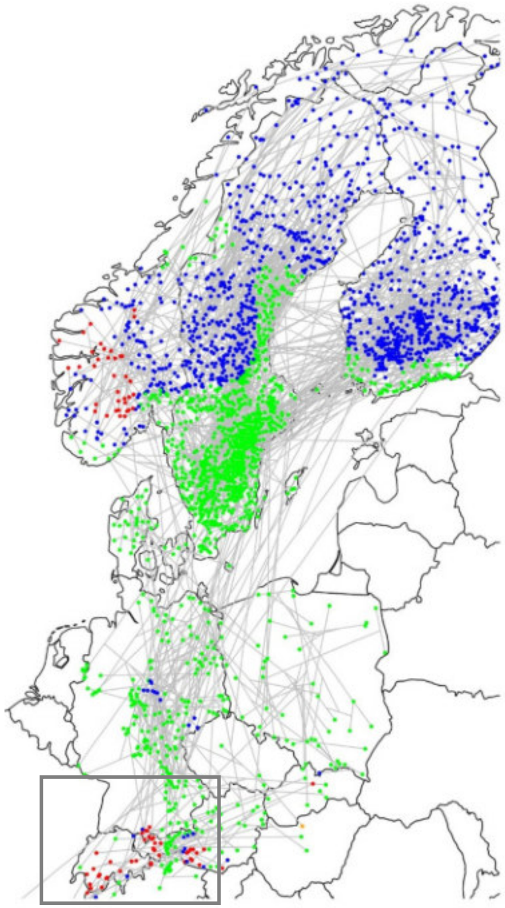


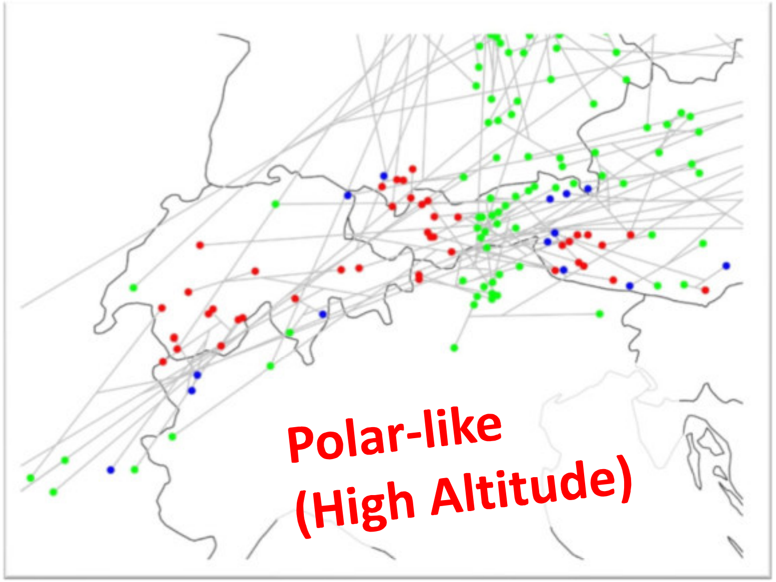
Ecoregion:
Blue =Taiga
Green = Sarmatic mixed forests
Red = Montane Birch Forest + grassland

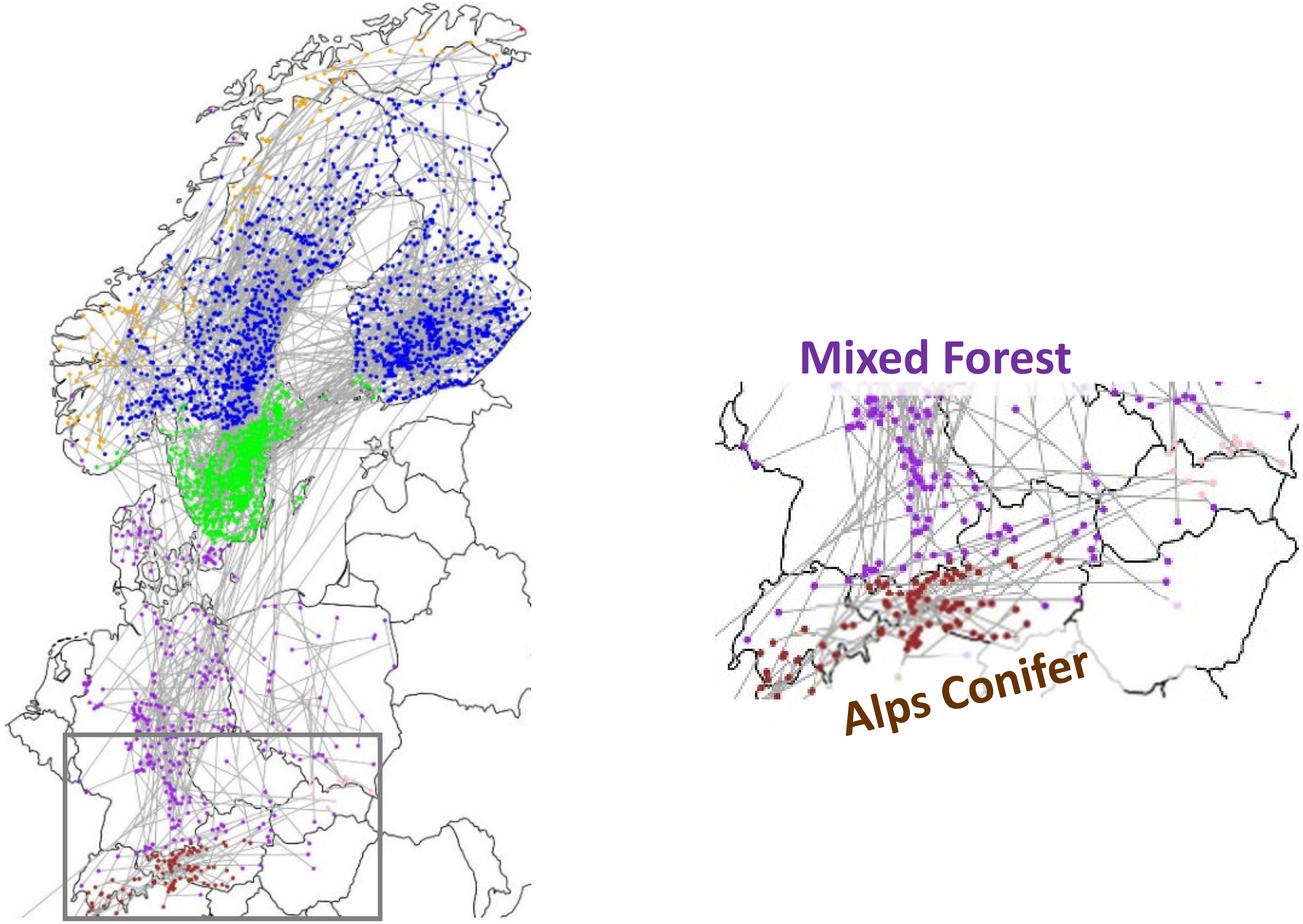

Cold year-round
Warm
summer


Birch Forest + Grassland
Kola Tundra
Taiga


Polar-like
Cold
year-round
Warm
summer



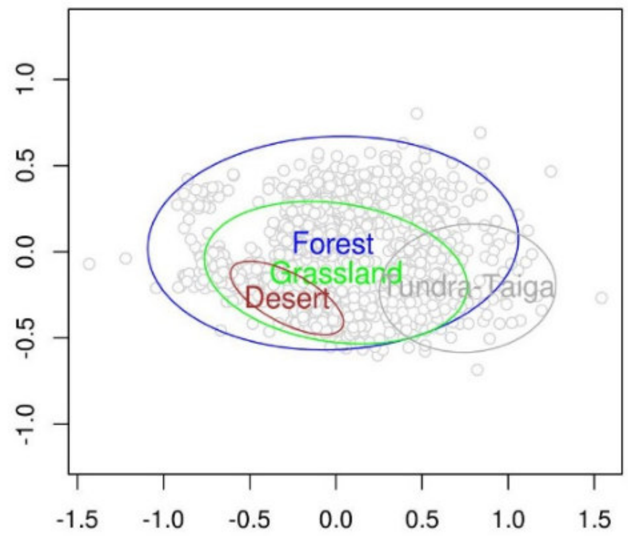

Polar-like
(High Altitude)

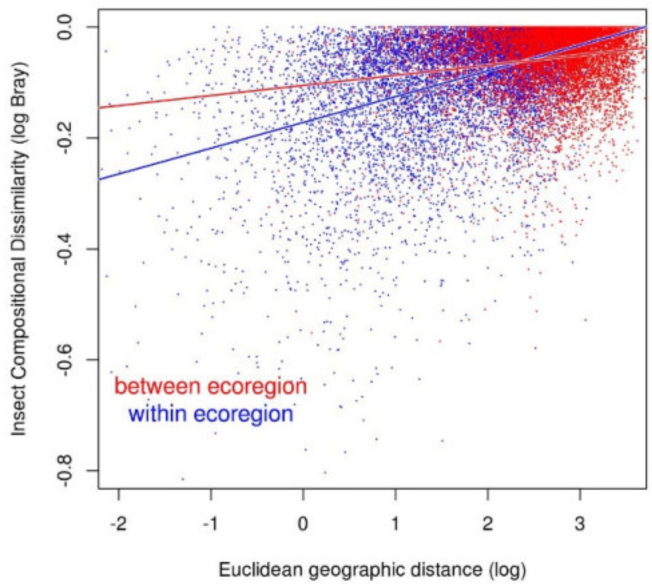


Mixed Forest
Alps Conifer

Results

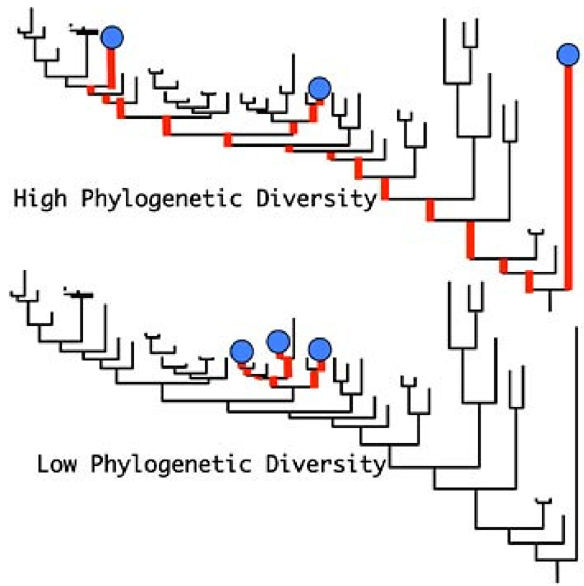
- Insect compositional dissimilarity corresponds higher to ecoregion than clime or RS-derived vegetation parameters
- Forests comprise majority of variation, although unique compositions also observed in tundra-taiga of N. America
- Beta diversity greater between classes (ecoregion or clime) than within, although spatially dependent:
  - towards continental scale, beta diversity rises more within ecoregion





Results, composition beyond shared species

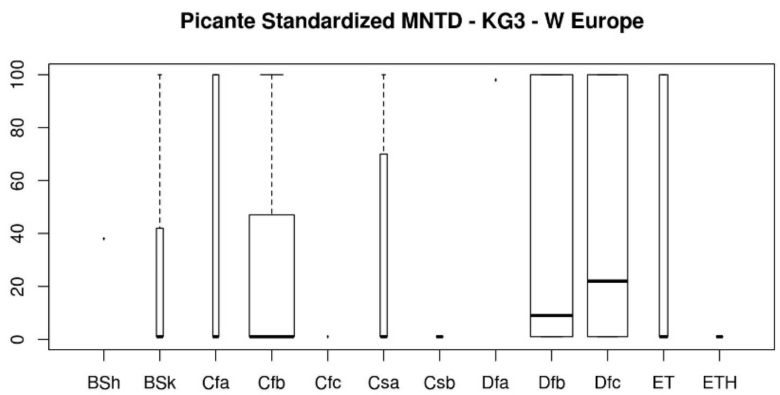
		Ecoregion	Clime
Beta	Species Composition	Anosim r=0.70, p<0.001	Anosim r=0.32, p<0.001
	Phylogenetic Diversity	Anosim r=-0.48, p=1	Anosim r=-0.23, p=1
	Mean Phylogenetic Diversity	Anosim r=0.13, p=0.001	Anosim r=-0.01, p=0.67
	Mean Nearest Taxon Distances	Anosim r=0.45, p=0.001	Anosim r=0.13, p=0.001
Alpha	Mean Nearest Taxon Distance	Kruskall-Wallis df=27, p<0.001	Kruskall-Wallis df=11, p<0.001

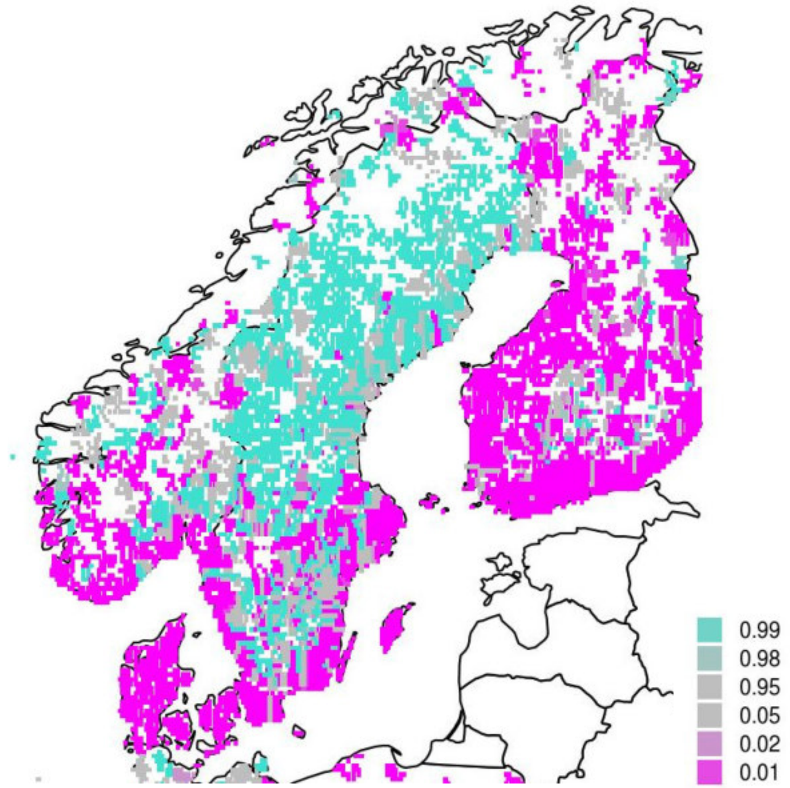


http://vcresearch.berkeley.edu/

Results, compositional dissimilarity beyond shared species: Mean Nearest Taxon Distance (MNTD)

- Phylogenetic information often viewed as proxy for traits, as relatives usually sharing many traits
- High MNTD in year-round cold and wet areas of Sweden



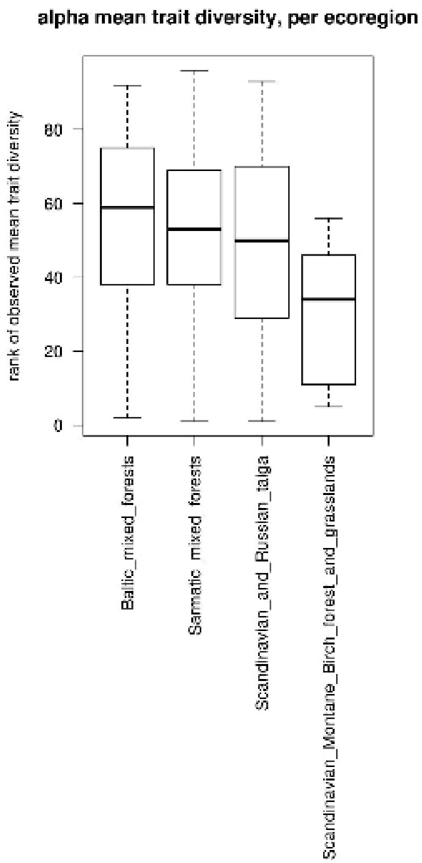


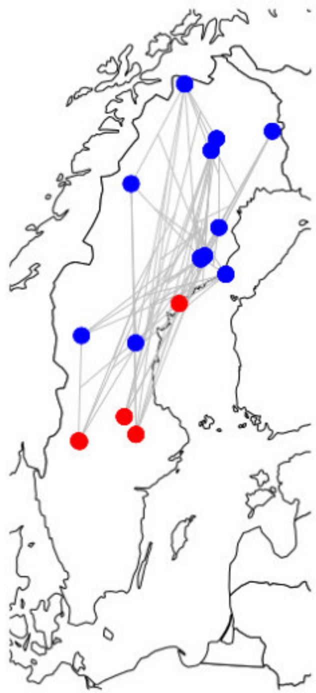
Improving the system

- Data quality:
  - Currently opportunistic use of observation data (region and taxon bias)
  - Standardized programs such as Malaise trapping with metabarcoding, objective and quantified
- Traits:
  - Are central to understanding compositions in plant ecology.
  - There are very few comprehensive trait databases for invertebrates
  - Recently proposed terrestrial invertebrates traits sensitive to global stressors (Moretti et al. 2017).
- Evolving land and climate classifications
  - Statistical stratification partition variation in independent variables,
  - key variables include temperature, seasonality, growing degree-days, reflecting temperature gradients; aridity
- Climate projections (IPCC) permit predication on different scenarios (macro-ecological modelling)

Improving the system

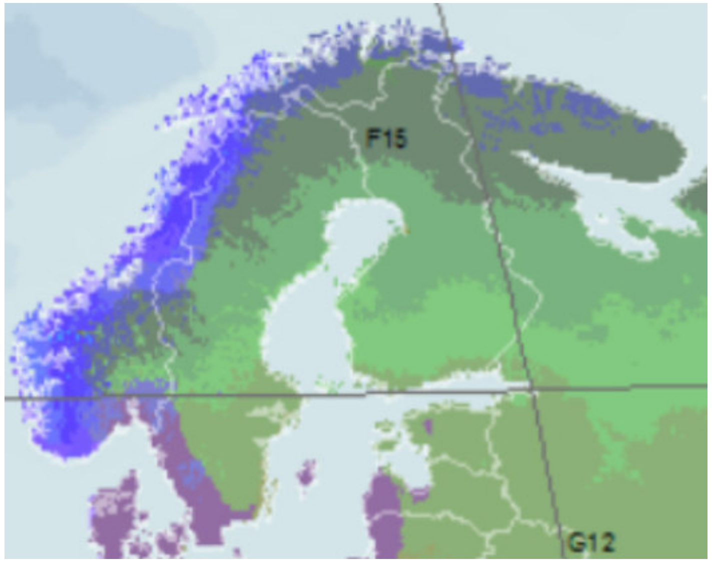
- Data quality:
  - Currently opportunistic use of observation data (region and taxon bias)
  - Standardized programs such as Malaise trapping with metabarcoding, objective and quantified
- Traits:
  - Are central to understanding compositions in plant ecology.
  - There are very few comprehensive trait databases for invertebrates
  - Recently proposed terrestrial invertebrates traits sensitive to global stressors (Moretti et al. 2017).
- Evolving land and climate classifications
  - Statistical stratification partition variation in independent variables,
  - key variables include temperature, seasonality, growing degree-days, reflecting temperature gradients; aridity
- Climate projections (IPCC) permit predication on different scenarios (macro-ecological modelling)





Improving the system

- Data quality:
  - Currently opportunistic use of observation data (region and taxon bias)
  - Standardized programs such as Malaise trapping with metabarcoding, objective and quantified
- Traits:
  - Are central to understanding compositions in plant ecology.
  - There are very few comprehensive trait databases for invertebrates
  - Recently proposed terrestrial invertebrates traits sensitive to global stressors (Moretti et al. 2017).
- Evolving land and climate classifications
  - Statistical stratification partition variation in independent variables,
  - key variables include temperature, seasonality, growing degree-days, reflecting temperature gradients; aridity
- Climate projections (IPCC) permit predication on different scenarios (macro-ecological modelling)



Metzger et al. 2013

Improving the system

- Data quality:
  - Currently opportunistic use of observation data (region and taxon bias)
  - Standardized programs such as Malaise trapping with metabarcoding, objective and quantified
- Traits:
  - Are central to understanding compositions in plant ecology.
  - There are very few comprehensive trait databases for invertebrates
  - Recently proposed terrestrial invertebrates traits sensitive to global stressors (Moretti et al. 2017).
- Evolving land and climate classifications
  - Statistical stratification partition variation in independent variables,
  - key variables include temperature, seasonality, growing degree-days, reflecting temperature gradients; aridity
- Climate projections (IPCC) permit predication on different scenarios (macro-ecological modelling)

Conclusions

More information than climate / vegetation alone, is required for describing insect compositional variation

Compositional dissimilarity greater between sites of differing habitat/ climes, although spatially dependent at national-continental scale

Acknowledgements

Funded by

National Science Foundation of China

Chinese Academy of Sciences

DFG Germany

Insect photos provided by

Ken Dolbear

Thanks for listening

welcome to contact me: dchesters@ioz.ac.cn

INSTITUTE OF ZOOLOGY CAS

中国科学院动物研究所