# Invasive species in high latitude freshwater ecosystems as climate is warming

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ESENIAS training course 3 – 4 April 2017, Sofia, Bulgaria

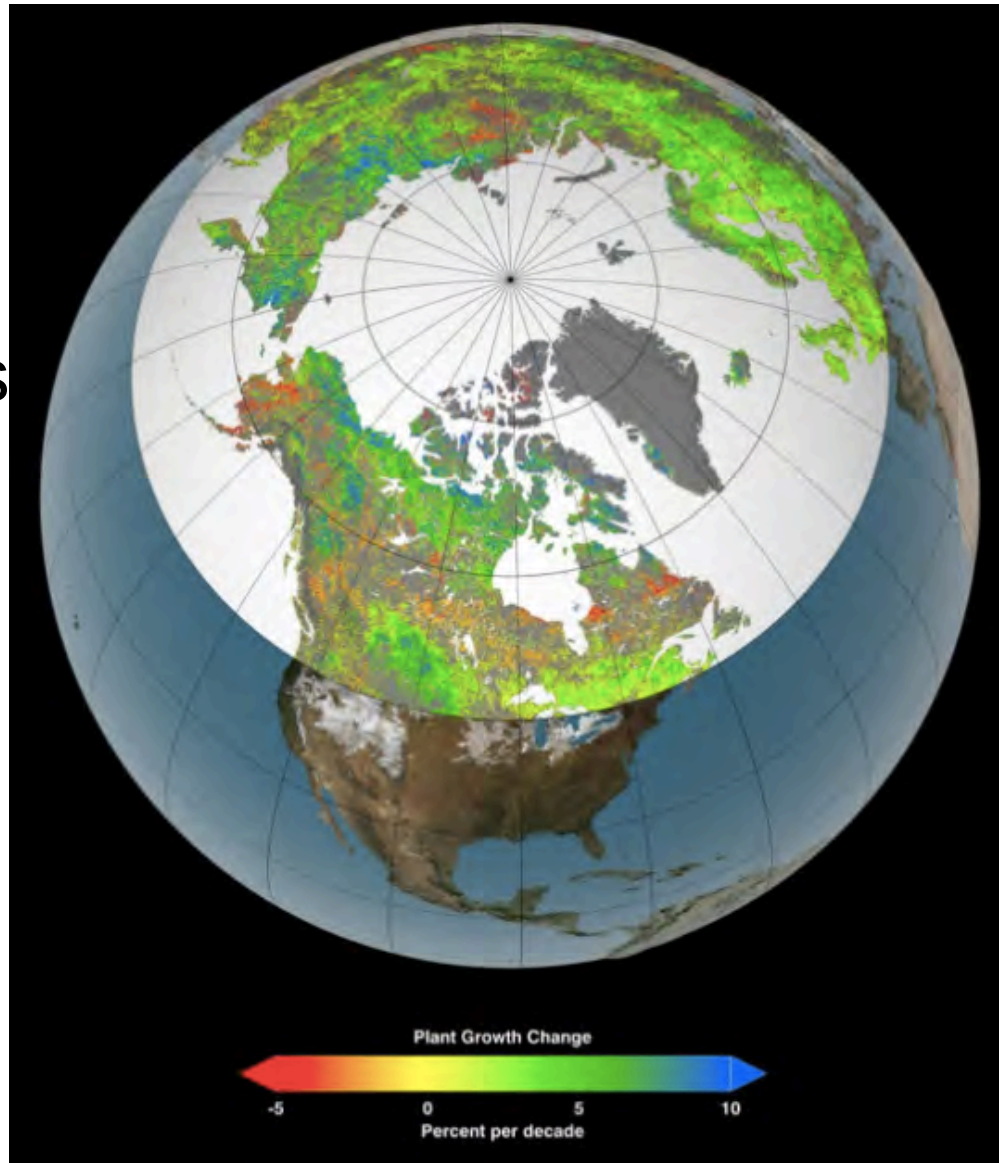
# Drivers

Two of the key drivers of biodiversity loss are climate change and invasive species

# The scenario

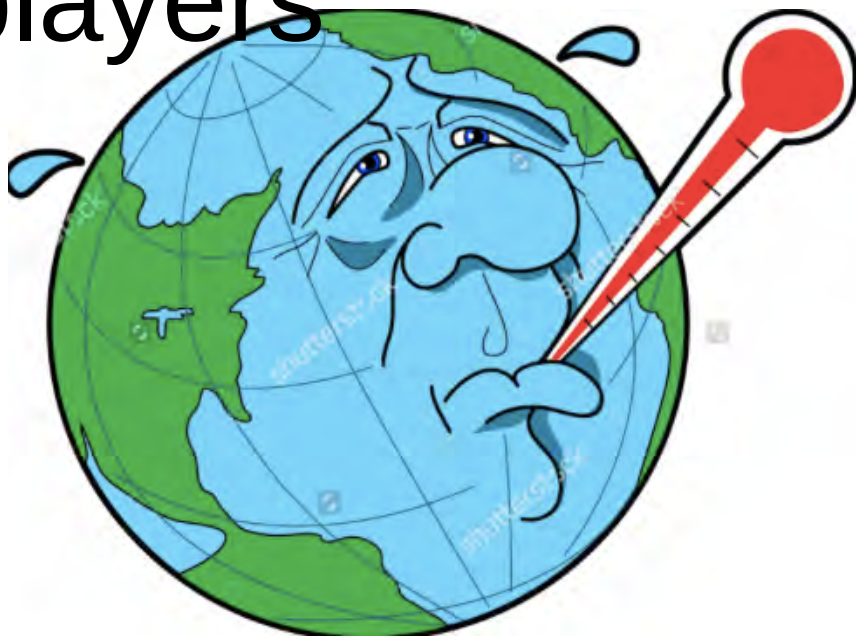
High latitude ecosystems

- freshwaters; lakes, stream and wetlands

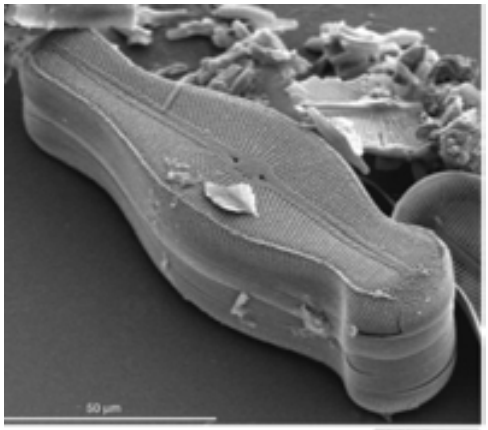


# The main players

Global warming



Invasion of alien species



# Warming up; .....

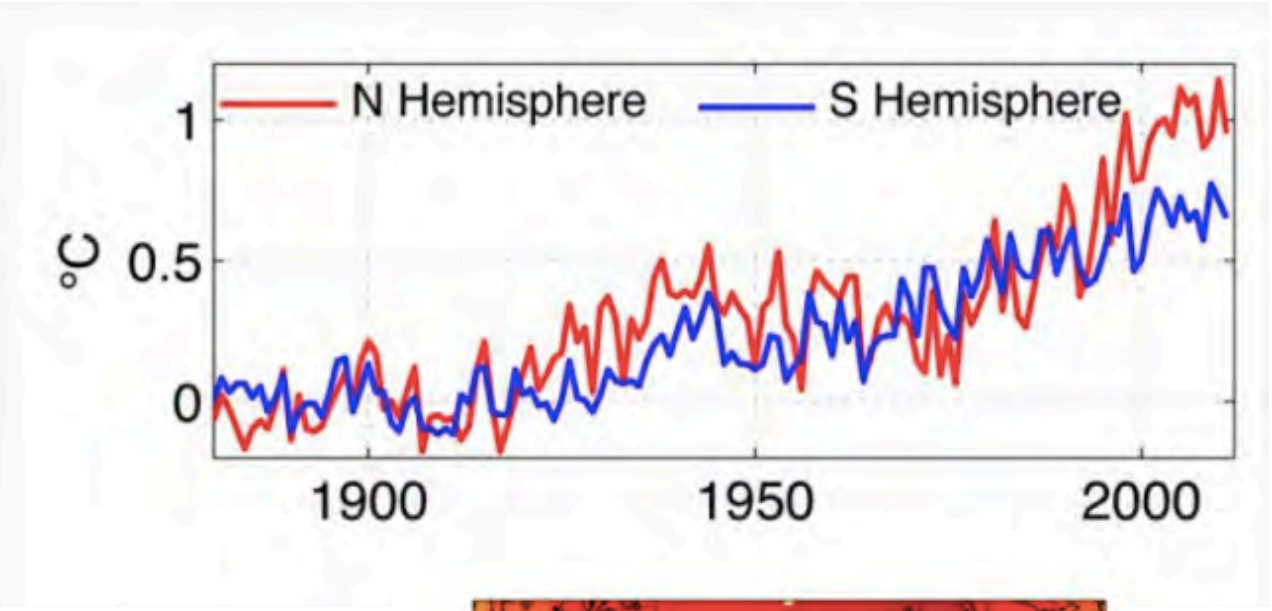

IPCC (2007)

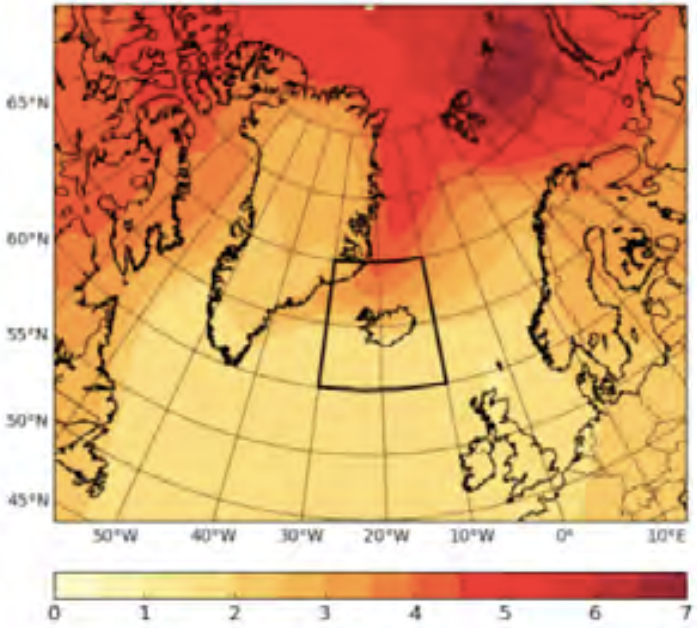
# Content

- Review – background
- Stream experiments in the sub-arctic
- Melting of the Arctic
- Invasive taxa – are they always making things worse?

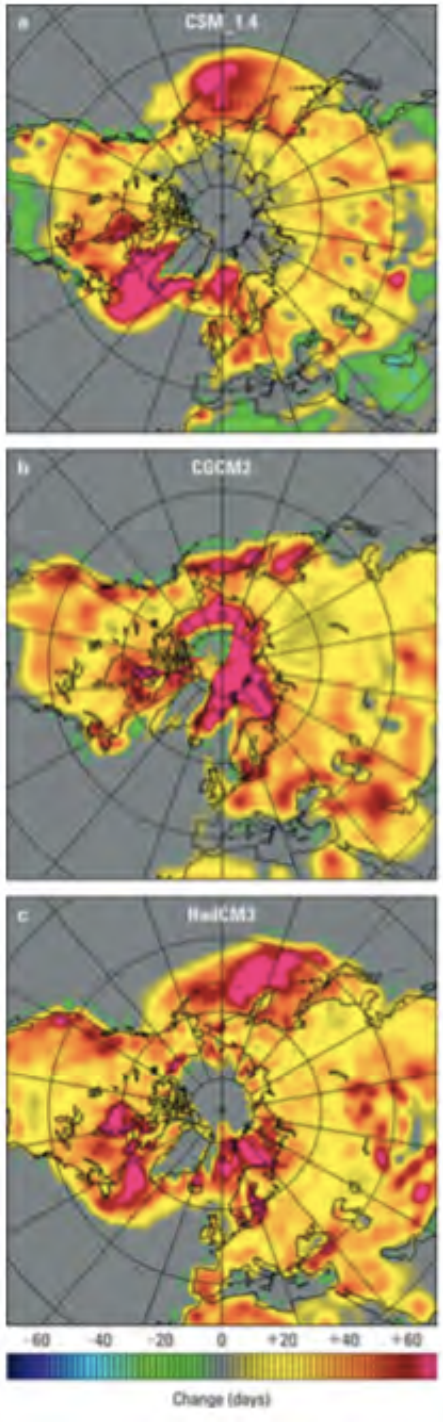

Climate change is presently affecting the Arctic and subarctic region faster than any place on earth.

Rapid climate change is making the Arctic region more vulnerable to invasive species introduction, at the same time a rapid surge in human activity, transit, and energy development, which is increasing the chance of introduction of new and invasive species.




Warming in the North Atlantic until 2100




Projected changes in the length of the growing season defined as the number of days where the minimum temperature is greater than 0 deg. C until 2100, based on three different models.

Wrona et al. 2006. Climate change effects on aquatic biota, ecosystem structure and function. Ambio 35(7):359–369

- The Arctic region contains a remarkable diversity of habitats and associated ecosystems, from mountain glaciers and ice caps to tundra, inland waters, and icy seas.
- The impacts of warming will have direct consequences for people living in the North via changes in ecosystem services, and interact consequences elsewhere, for example via changes in global biodiversity, biogeography, and biogeochemical fluxes.

Vincent et al. 2011. Ecological Implications of Changes in the Arctic Cryosphere. AMBIO 2011 40:87–99

Range-restricted species, particularly, polar and mountaintop species, show severe range contractions and have been the first groups in which entire species have gone extinct due to recent climate change.

Camille Parmesan 2006. Ecological and Evolutionary Responses to Recent Climate Change.
Annu. Rev. Ecol. Evol. Syst. 37:637–669

In the Northern Hemisphere, the range of terrestrial plants and animals has shifted on average, 6.1 km per decade northward

Thuiller, W. 2007. Climate change and the ecologist. Nature 448:550–552

- Climate change is very likely to have both direct and indirect consequences on the biota and the structure and function of arctic freshwater ecosystems.
- The consequences may be in attributes such as species richness, biodiversity, range of distribution, and consequently alter corresponding food web structures and primary- and secondary production.

Wrona et al. 2006. Climate change effects on aquatic biota, ecosystem structure and function. Ambio 35(7):359–369

- Global warming has enabled alien species to expand into regions in which they previously could not survive and reproduce in.
- **Alien:** an organism occurring outside its natural past or present range and dispersal potential, whose presence and dispersal is due to intentional or unintentional human action.
- **Invasion/invasive**: refers to established alien organisms that are rapidly extending their range in the new region. (This is usually associated, although not necessarily for an organism to qualify as invasive, with causing significant harm to biological diversity, ecosystem functioning, socio-economic values and human health in invaded regions.)

Walther et al. 2009. Alien species in a warmer world: risks and opportunities
Trends in Ecology & Evoloution 24(12):686–693

# Managing Aquatic Species of Conservation Concern in the Face of Climate Change and Invasive Species

FRANK J. RAHEL,* BRITTA BIERWAGEN,† AND YOSHINORI TANIGUCHI‡

*Conservation Biology*, Volume 22, No. 3, 551–561

DOI: 10.1111/j.1523-1739.2008.00953.x

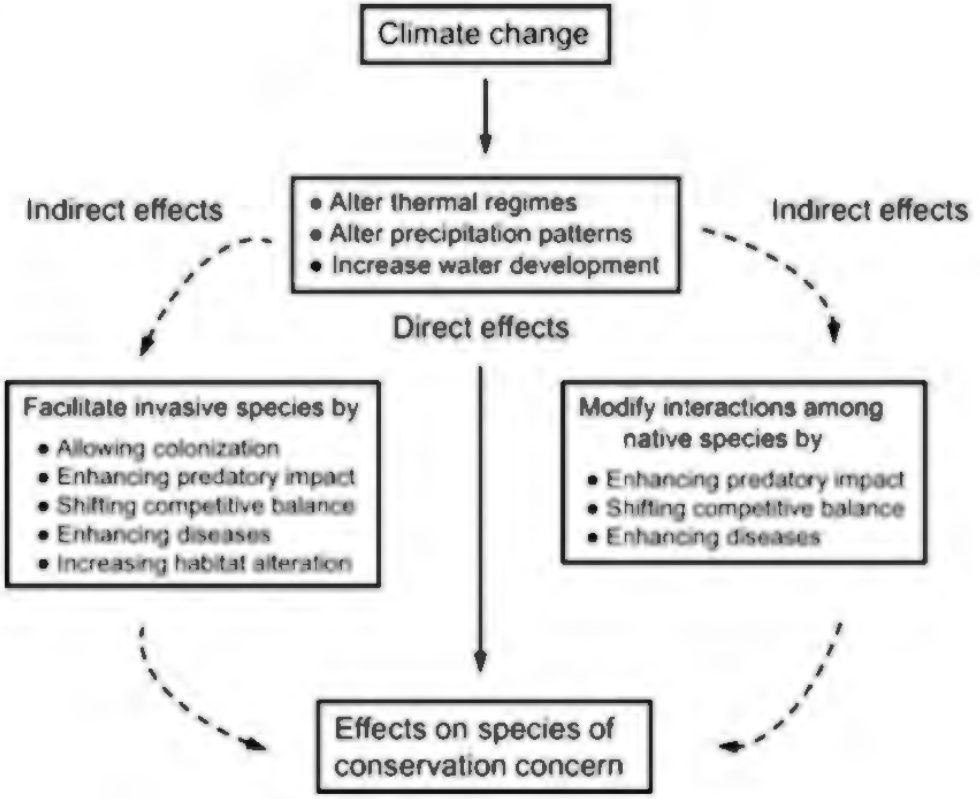



***Figure 1. The mechanisms by which climate change and invasive species are expected to affect species of conservation concern.***

# The population biology of invasive species

- Can invasiveness be predicted by life history traits?
- How do the genetic diversity and biology of invasive species differ in their native vs. introduced areas?
- Is environmental tolerance greater in invasive species?
- How does recipient environment affect the degree of invasiveness?
- What are the impacts of invasive species on biodiversity and how can these be measured?
- Can invasive taxa be considered as “key-stone taxa”?

# The population biology of invasive species

Most long-distance introductions of non-native taxa to new areas are the direct or indirect result of human activities, and social and economic factors are often as critical as biological factors in the introduction of species.

*Diversity and Distributions, (Diversity Distrib.)* (2005) 11, 149–156

BIODIVERSITY RESEARCH

# Recent advances in the study of long-distance dispersal of aquatic invertebrates via birds

Andy J. Green* and Jordi Figuerola

Waterfowls and shore birds as vectors in distributing organisms

Figure 3 Common cockle *Cerastoderma edule* attached to a Dunlin *Calidris alpina* mist-netted in the Odiel Marshes, Spain. Photo by José Manuel Sayago.

# The population biology of invasive species - conclusions

- The synergism arising from combining ecological, genetic and evolutionary perspectives on invasive species may be essential for developing practical solutions to the economic and environmental losses from these species. ECO-EVO approach
- One vital question is understand why some species become invasive and other do not.
- Are there possibilities that what has been regarded as an invasive taxa may not be an “aggressive” one?

- Climate change is expected to substantially alter biodiversity, causing changes in phenology, genetic composition, and species ranges, and affecting species interactions and ecosystem processes.
- Invasive species will also respond to climate change, and their responses will have ecological and economic implications.
- Invasive species typically are successful and abundant, whereas many native species are rare.

Hellmann et al. 2007. Five potential consequences of climate change for invasive species. Conservation Biology 22(3): 534 - 543

# Alien species in a warmer world: risks and opportunities

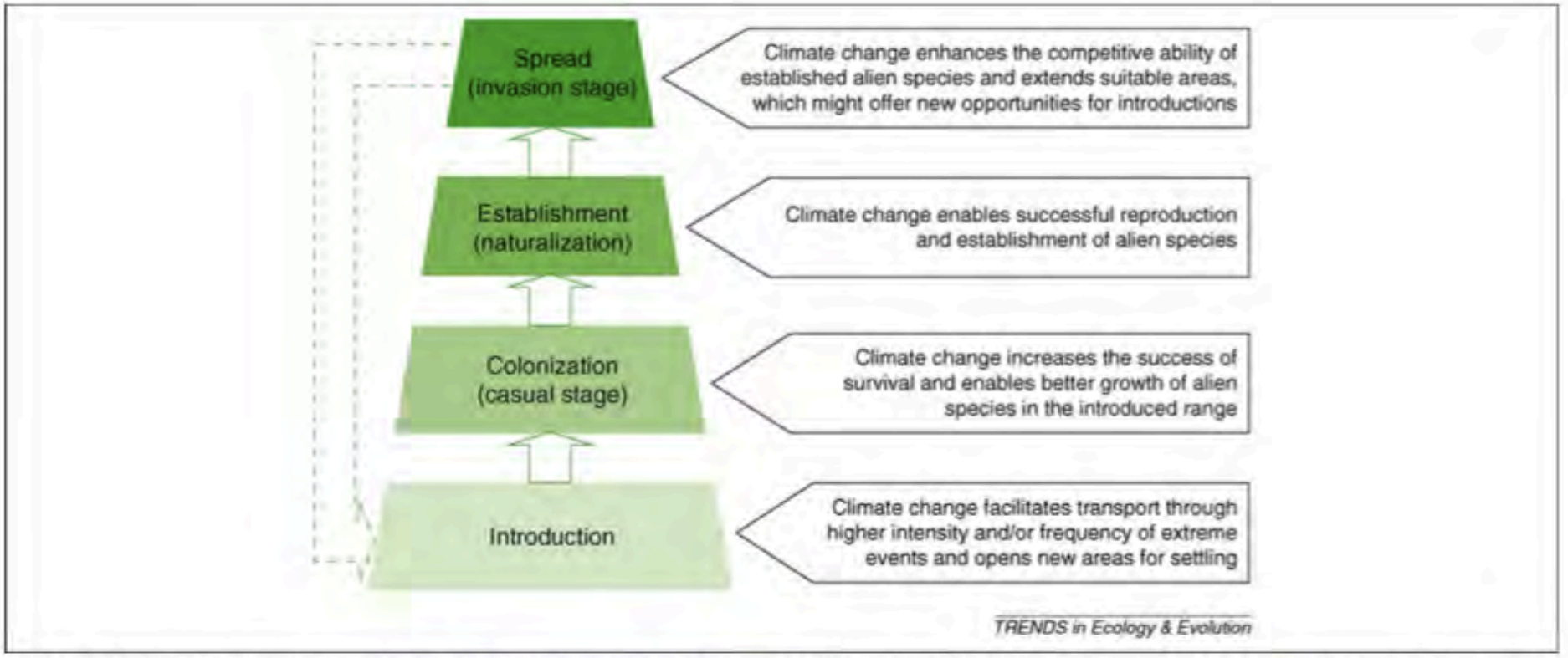



**Figure 1.** Influence of climate change on all the sequential transitions of a successful invasion process. Based on the scheme of Ref. [10], with their terms indicated in parentheses. For examples, see text and Online Supplementary Material.

Walther et al. 2009. Alien species in a warmer world: risks and opportunities
Trends in Ecology & Evoloution 24(12):686–693

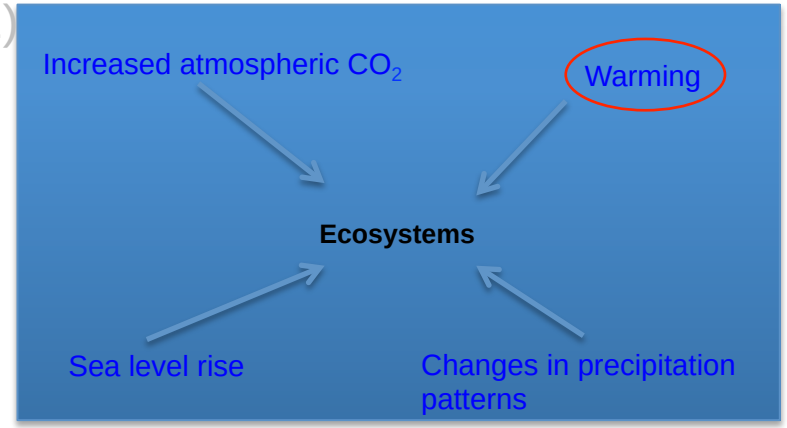
CAFF Strategy Series Report No. 8
May 2016

# Arctic Invasive Alien Species (ARIAS) "Action Plan"

Workshop report, Akureyri, Iceland, March 30- April 1, 2016

# Warming up; ecosystem function

(1)

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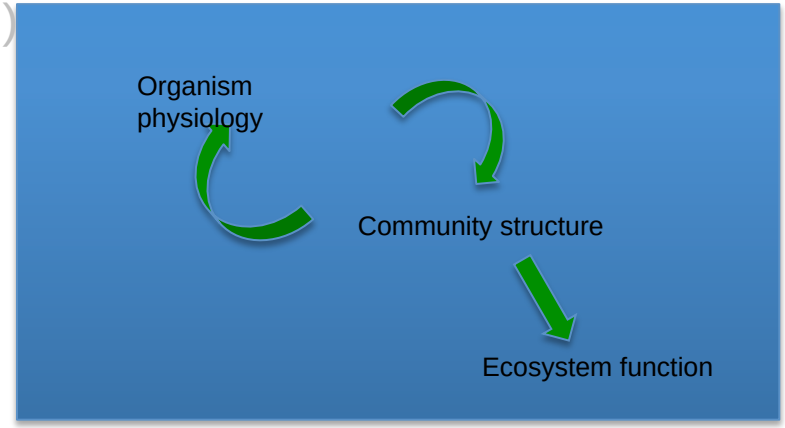
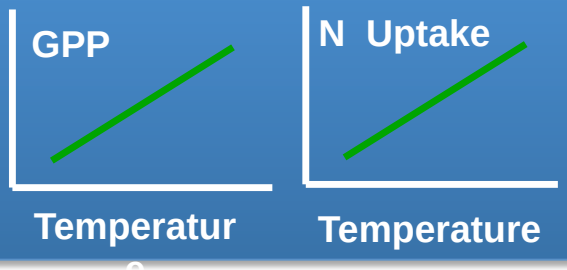
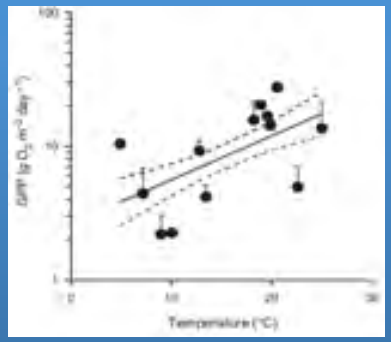



(3)

**Predictions:**
**Under N-limited conditions with fixed N supply**




(4)



**Demars et al. 2011, Freshwater Biology**

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

*Phil. Trans. R. Soc. B* (2010) **365**, 2093–2106
doi:10.1098/rstb.2010.0055

inel systems?

*Review*

# Climate change and freshwater ecosystems: impacts across multiple levels of organization

**Guy Woodward**[1,*],

[1]*School of Biological and Chemical*
[2]*School of Geog*

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PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

*Phil. Trans. R. Soc. B* (2010) **365**, 2117–2126
doi:10.1098/rstb.2010.0038

# Warming alters the metabolic balance of ecosystems

Global Change Biology

Global Change Biology (2014) **20**, 3291–3299, doi: 10.1111/gcb.12602

OPINION

# Climate change and geothermal ecosystems: natural laboratories, sentinel systems, and future refugia

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JAMES M. HOOD[3], PHILI
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[2]*Department of Biological Sciences,*
*University, Bozeman, MT 59717, U*
*Norway,* [5]*Department of Civil, Con*
[6]*Agricultural University of Iceland,*

Global Change Biology

Global Change Biology (2010) **16**, 1979–1991, doi: 10.1111/j.1365-2486.2009.02052.x

# Sentinel systems on the razor's edge: effects of warming on Arctic geothermal stream ecosystems

GUY WOODWARD*, JOHN B. DYBKJÆR†, JÓN S. ÓLAFSSON‡, GÍSLI M. GÍSLASON§, ELÍSABET R. HANNESDÓTTIR§ and NIKOLAI FRIBERG†¶

*School of Biological & Chemical Sciences, Queen Mary University of London, London E1 4NS, UK, †Department of Freshwater Ecology, National Environmental Research Institute, University of Aarhus, Vejlsøvej 25, DK-8600 Silkeborg, Denmark, ‡Institute of Freshwater Fisheries, Keldnaholt, IS-112 Reykjavik, Iceland, §Institute of Biology, University of Iceland, Sturlugata 7, IS-101 Reykjavik, Iceland, ¶Macaulay Land Use Research Institute, Catchment Management Group, Craigiebuckler, Aberdeen AB15 8QH, UK*

*Advances in Ecological Research*, Volume 48
ISSN 0065-2504
http://dx.doi.org/10.1016/B978-0-12-417199-2.00005-7


# Increased Stream Productivity with Warming Supports Higher Trophic Levels☆

Elísabet Ragna Hannesdóttir*,†, Gísli Már Gíslason*, Jón S. Ólafsson†, Ólafur Patrick Ólafsson*, Eoin J. O'Gorman‡,§
*Institute of Life and Environmental Sciences, University of Iceland, Reykjavík, Iceland
†Institute of Freshwater Fisheries, Reykjavík,
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§Imperial College London, Silwood Park Ca
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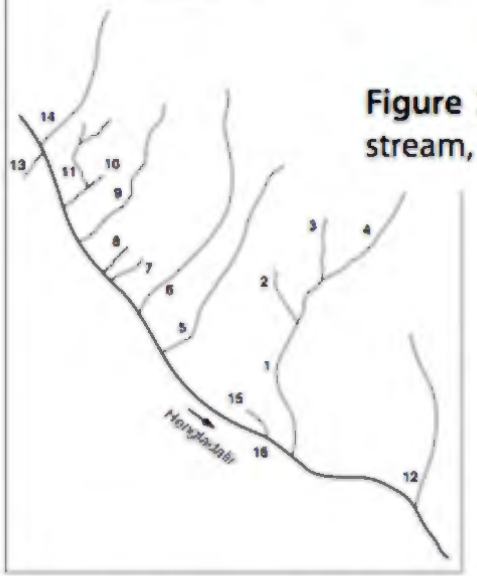


Fig. 1 Map of the 15 streams within the geothermal Hengill region of Iceland. Stream numbers are annotated on the map, with associated mean temperatures given in Table 1.

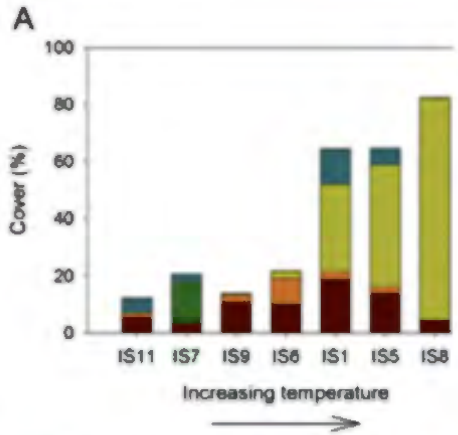


**Figure 2** Average annual (A) stream, showing the dominan

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 19.5 | 18.8 | | | | | | | |
| 7 | 7.7 | 7.1 | | | | | | | |
| 8 | 23.5 | 23.4 | | | | | | | |
| 9 | 14.9 | 14.6 | | | | | | | |
| 10 | 4.7 | 4.3 | | | | | | | |
| 11 | 11.2 | 10.5 | | | | | | | |
| 12 | 14.8 | 13.50 (0.54) | 7.8 | 165 | 107.6 | 10.10 | 0.022 | 0.017 | 9.06 | 43 |
| 13 | 6.8 | 6.71 (0.02) | 7.7 | 175 | 24.3 | 10.10 | 0.015 | 0.013 | 13.78 | 78 |
| 14 | 9.5 | 8.44 (0.33) | 8.2 | 182 | 28.3 | 11.10 | 0.015 | 0.010 | 9.22 | 0 |
| 15 | 43.0 | 43.00 (NA*) | 7.5 | 512 | 1.8 | 5.71 | 0.050 | 0.069 | 2.79 | 100 |

*Single spot sample, due to instrument failure over the full sampling period.



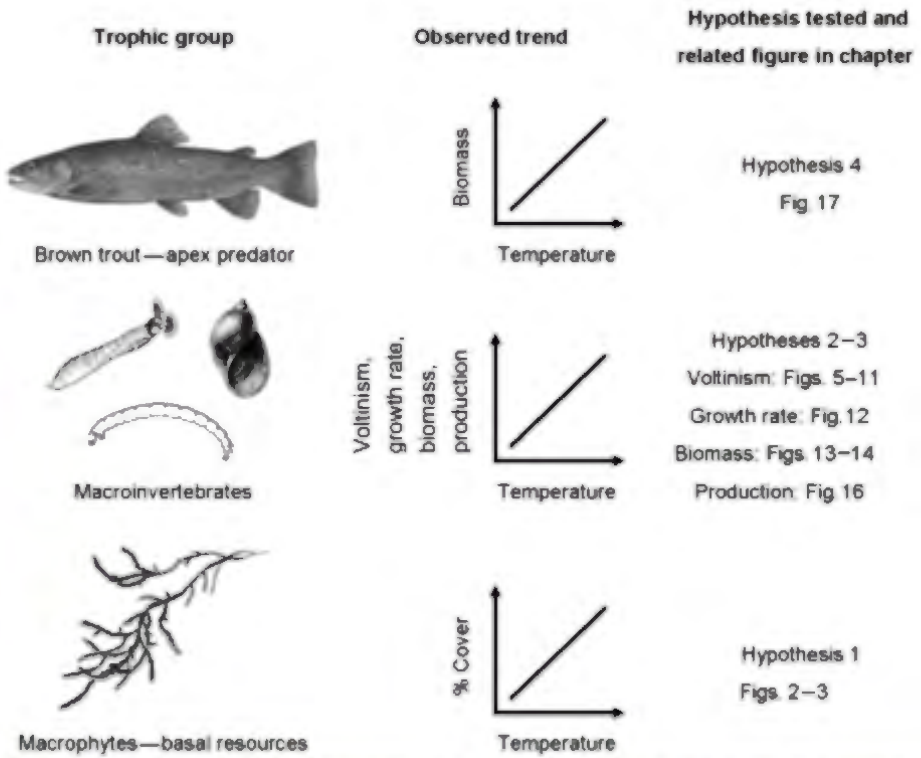


**Figure 18** Conceptual figure highlighting the main findings of the study. The general response to temperature for key characteristics of three major trophic groups are provided: fish, macroinvertebrates and basal resources (ordered by trophic height in the figure). The hypotheses tested in each case are listed, mapping onto the numbers provided at the end of the introduction. A list of figures relating to each observed trend is also shown. *Line drawings adapted from images on Wikimedia Commons.*

# Warming up; tipping point

review article

## Catastrophic shifts in ecosystems

Marten Scheffer*, Steve Carpenter†, Jonathan A. Foley‡, Carl Folke§ & Brian Walker‖

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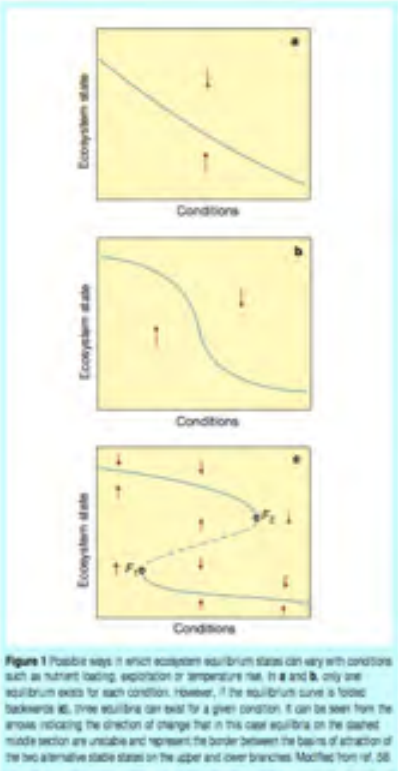
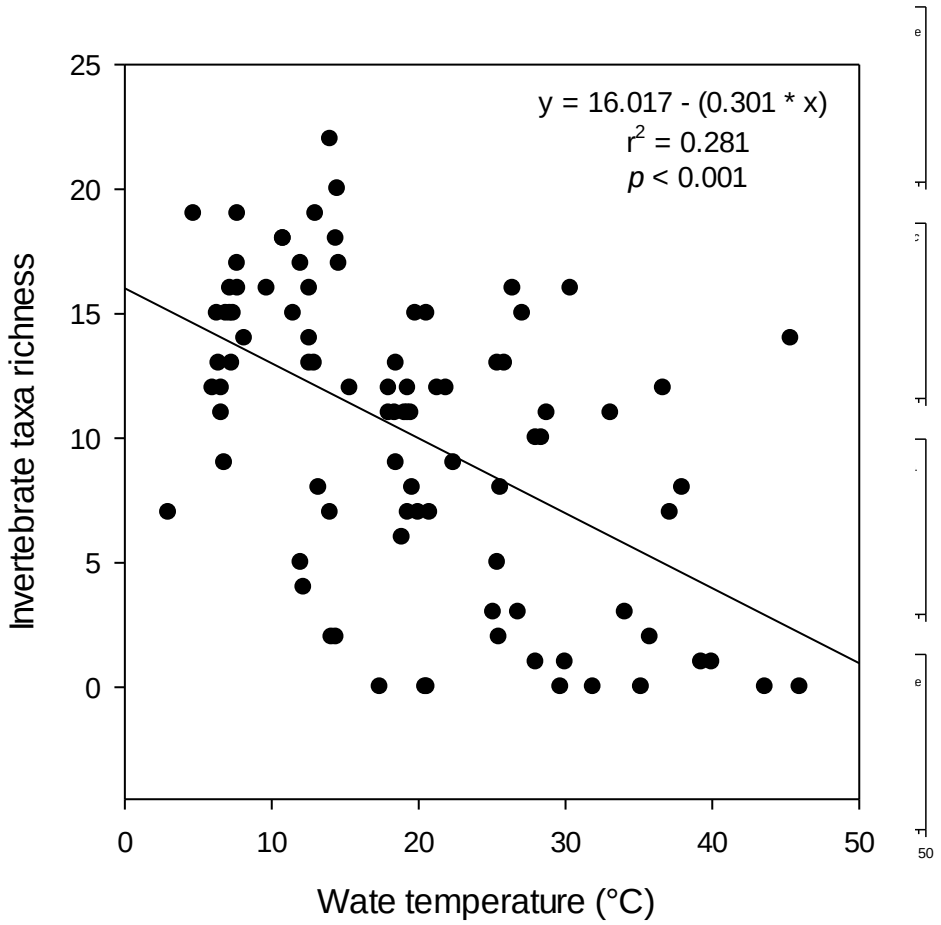
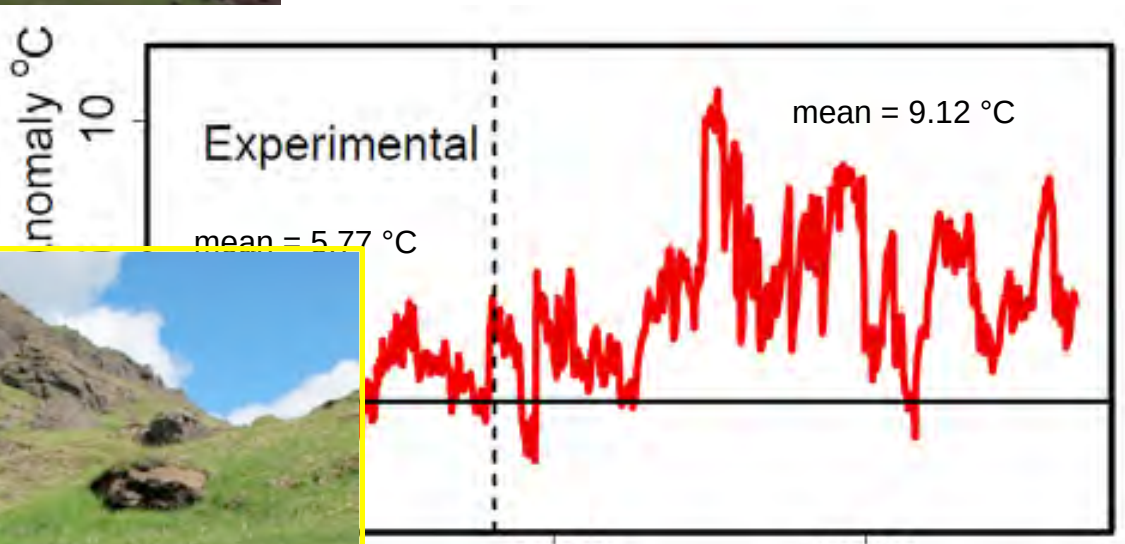


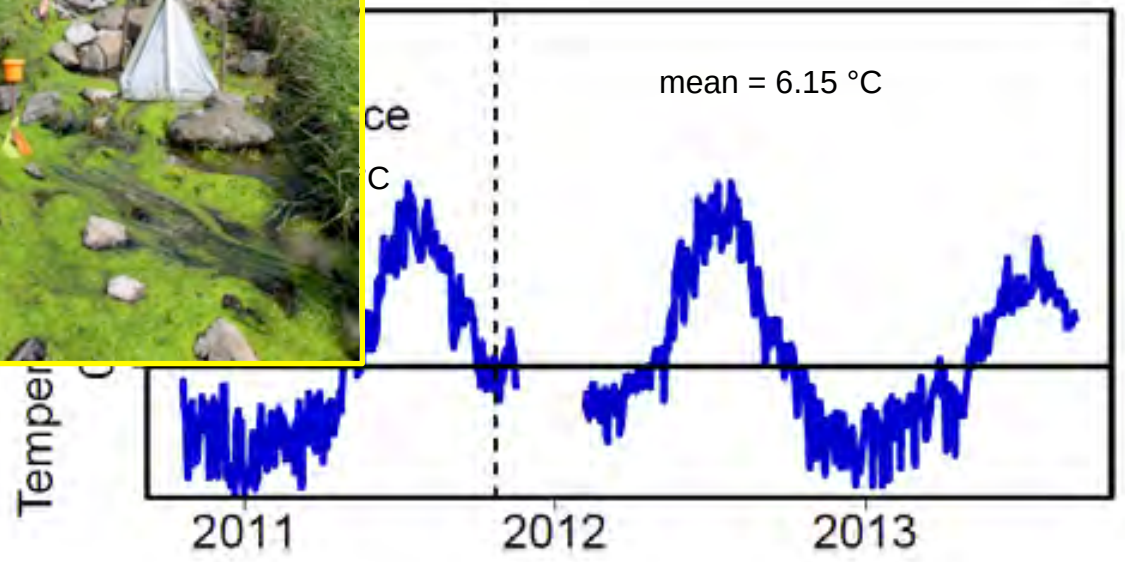

Figure 1 Possible ways in which ecosystem equilibrium states can vary with conditions such as nutrient loading, exploitation or temperature rise. In a and b, only one equilibrium exists for each condition. However, if the equilibrium curve is folded backwards (c), three equilibria can exist for a given condition. It can be seen from the arrows indicating the direction of change that in this case equilibria on the dashed middle section are unstable and represent the border between the basins of attraction of the two alternative stable states on the upper and lower branches. Modified from ref. 58.




Olafsson et al. 2010

2) Pipe taking cold water to heat exchanger




Based on D. Nelson's PhD study

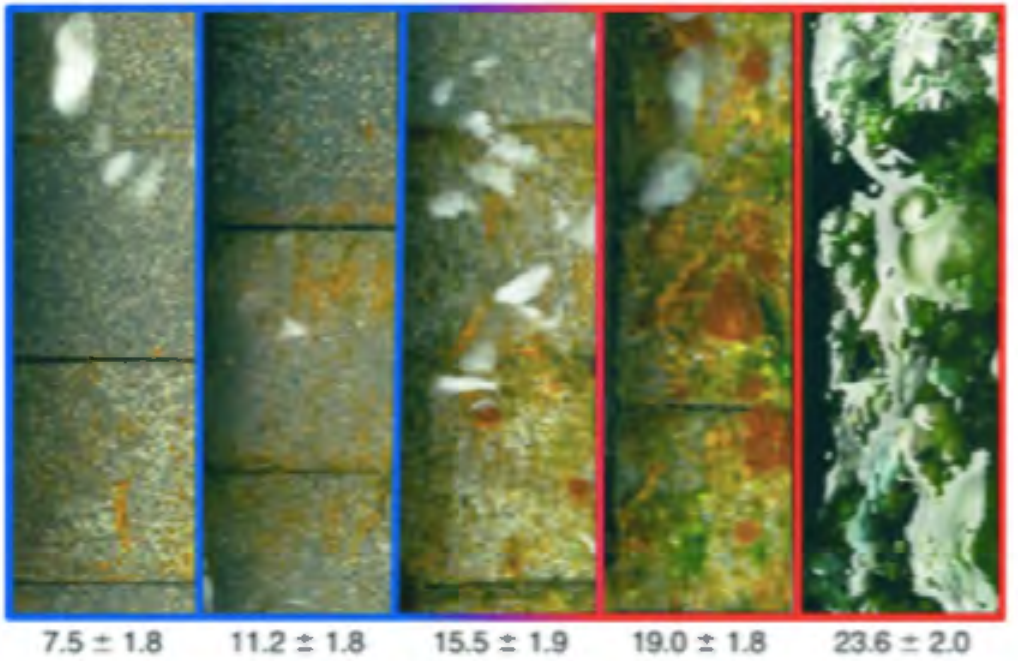



PLATE 1. (Top) Representative images of algal biomass in experimental stream channels 47 days post-deployment. The experimental temperature gradient was achieved by heating stream water from an unnamed tributary of the Hengladalsá River, Iceland (mean temperature = 7.5°C) using gravity-fed heat exchangers deployed in geothermal pools. Values represent mean temperature (±SD) in each treatment ($n$ = 3 channels per temperature, divided into three blocks with the five temperatures randomized within each block) over the course of the experiment. (Bottom) Experimental stream channel study site in the Hengill region of Iceland. Photo credits: top, T. J. Williamson; bottom, Jackie Goldschmidt.

*Ecology*, 96(3), 2015, pp. 603–610


# Does $N_2$ fixation amplify the temperature dependence of ecosystem metabolism?

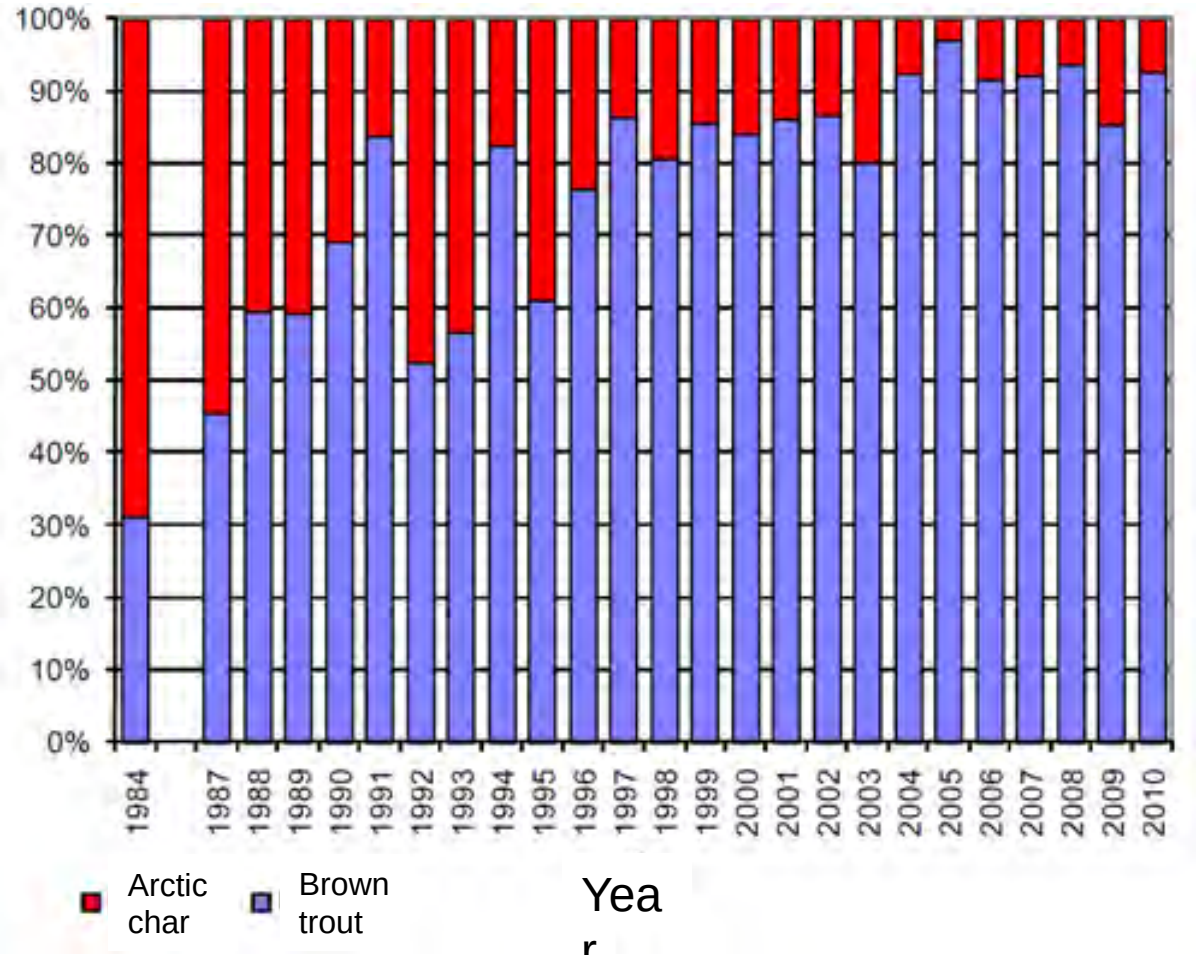
JILL R. WELTER,[1,5] JONATHAN P. BENSTEAD,[2] WYATT F. CROSS,[3] JAMES M. HOOD,[3] ALEXANDER D. HURYN,[2] PHILIP W. JOHNSON,[4] AND TANNER J. WILLIAMSON[3]

# Melting, fast!

# Retreating, new ecosystem emerges

# with an introduction of various organisms

# Proportion of Arctic char and Brown trout caught in gill nets in a lake, SW Iceland




*Antonsson & Arnason 2010*

# A happy gentleman, salmon catch up – arctic char down

**Fig. 4** Permafrost landscapes in transition. Thaw lakes and ponds are eroding and draining in some Arctic regions, while in other areas such as in here in Nunavik, Canada, they are expanding (Callaghan et al. 2011e; and references therein convert tundra soil carbon to greenhouse gases. Photocredit: Wa F. Vincent/CEN and ArcticNet

# Disappearing Arctic Lakes

L. C. Smith[1,*], Y. Sheng[2], G. M. MacDonald[1], L. D. Hinzman[3]

+ See all authors and affiliations

*Science* 03 Jun 2005:
Vol. 308, Issue 5727, pp. 1429
DOI: 10.1126/science.1108142


**Science**

Vol 308, Issue 5727
03 June 2005

Table of Contents

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE
10.1002/2014JG002778

Key Points:
- A reduction of net pond area and number was observed over a 65 year period
- Permafrost thaw, water loss, and aquatic vegetation contribute to pond reduction

# Disappearing Arctic tundra ponds: Fine-scale analysis of surface hydrology in drained thaw lake basins over a 65 year period (1948–2013)

**Christian G. Andresen[1] and Vanessa L. Lougheed[2]**

[1]Environmental Science and Engineering Program, University of Texas at El Paso, El Paso, Texas, USA, [2]Department of Biological Sciences, University of Texas at El Paso, El Paso, Texas, USA

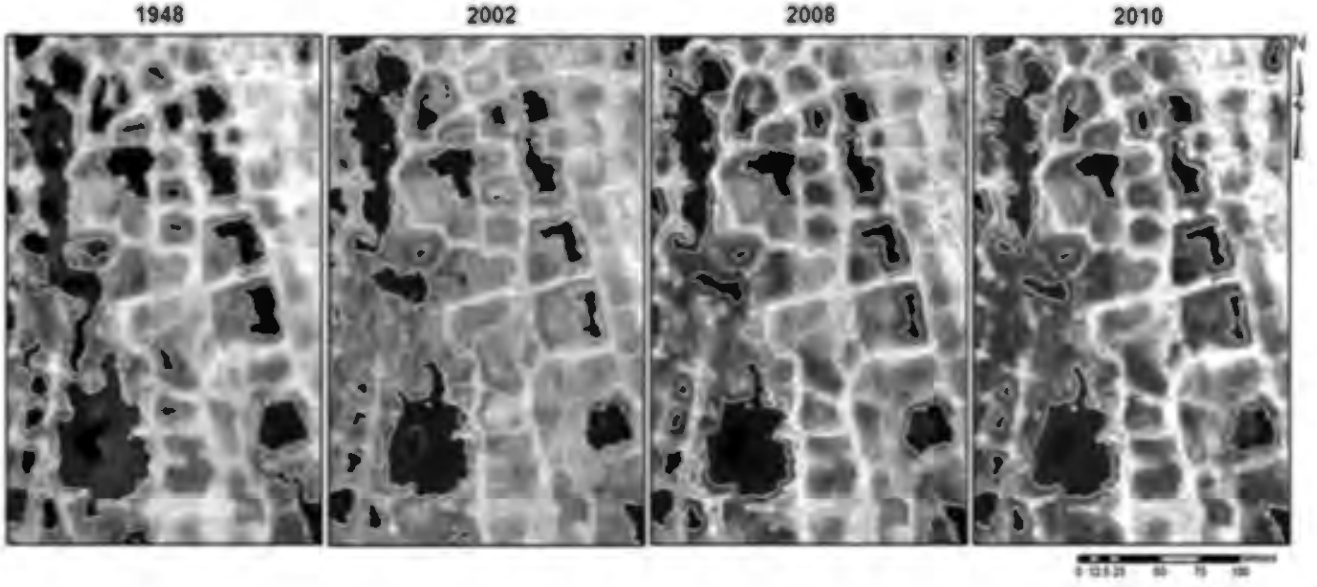



**Figure 3.** Imagery time series example depicting pond area and number loss at the IBP site (71°17'N, 156°41'W) from 1948 to 2010. White contours indicate delineated pond margins.

# Are all invasive species bad?

Fig. 1. Salmon fishing in the River Ellidaar in Reykjavik, Iceland. The photograph is taken 11 August 2007 downstream close to the river mouth. (Photo: Jón S. Ólafsson).

# The diet of chironomid larvae

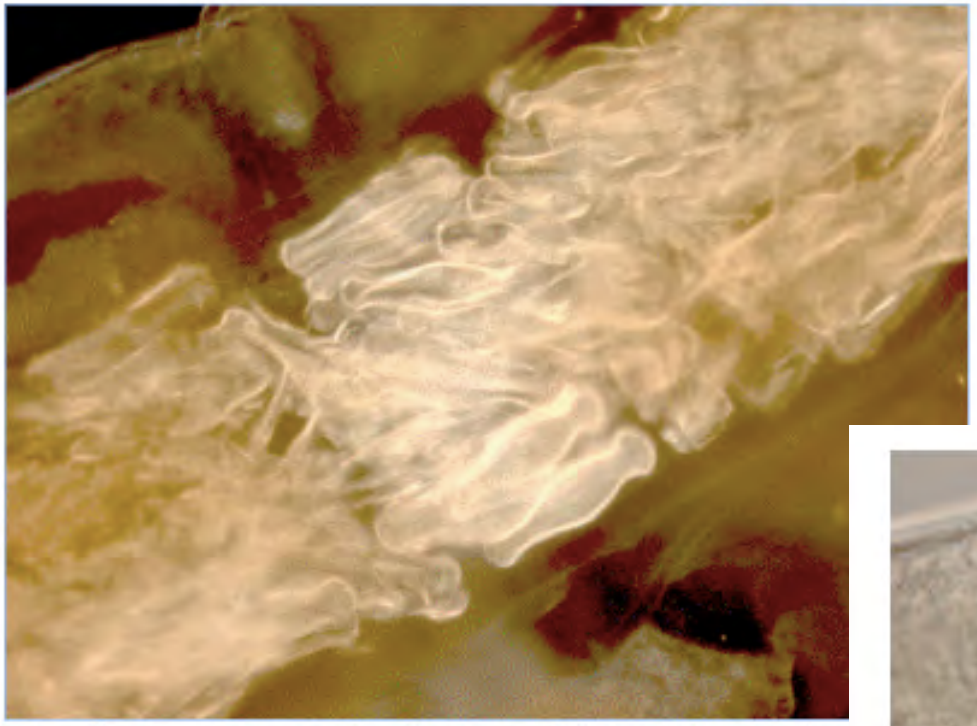


Fig. 5. *D. geminata* in the gut of fourth instar lar
*Diamesa* 1994.

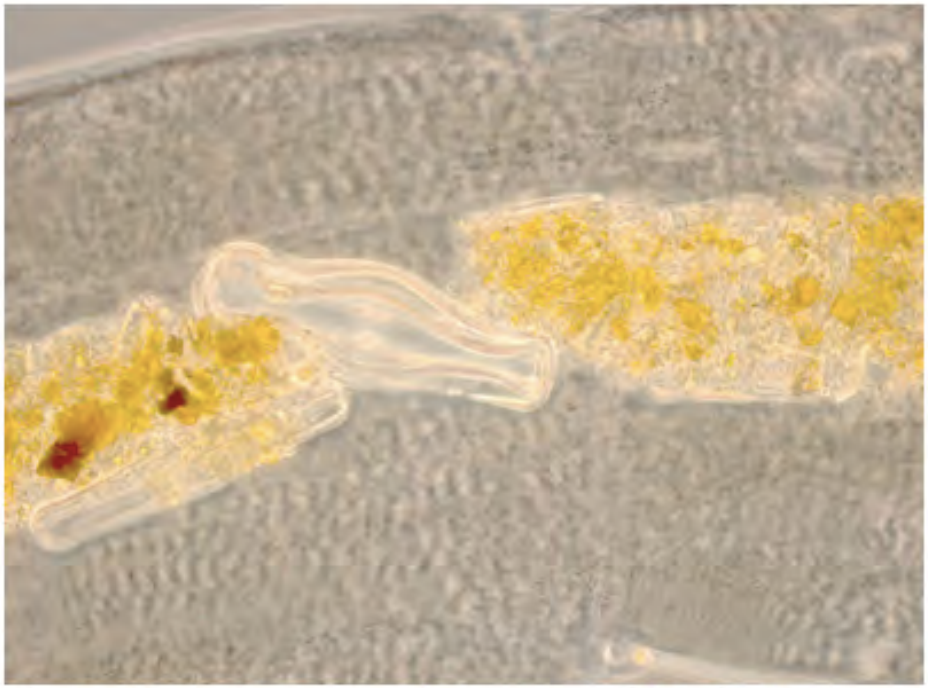


Fig. 6. The gut content of *E. minor*, whith detritus, *D. geminata* and other diatoms.

Olafsson et al. in prep.