



SCIENCE AND
EDUCATION **FOR**
SUSTAINABLE
LIFE

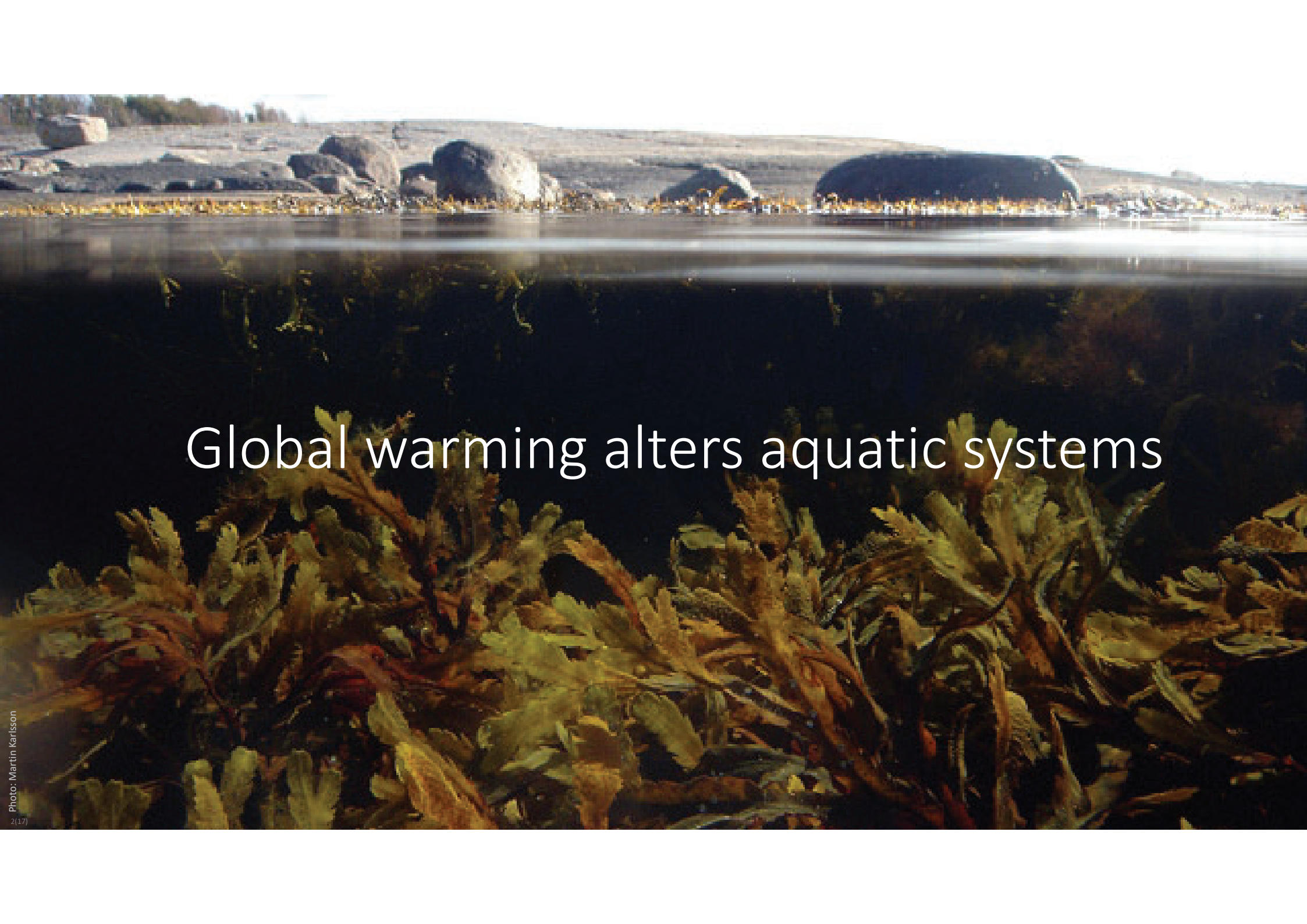
Speeding young & shrinking males – how global warming affects fish and aquatic foodwebs

Anna Gårdmark & Magnus Huss

anna.gardmark@slu.se , magnus.huss@slu.se

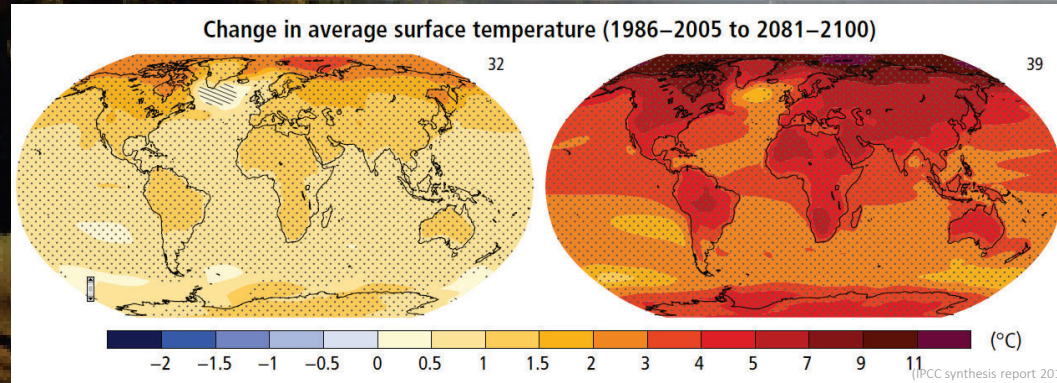
Dept. of Aquatic resources, SLU

www.slu.se/fishinfoodwebs

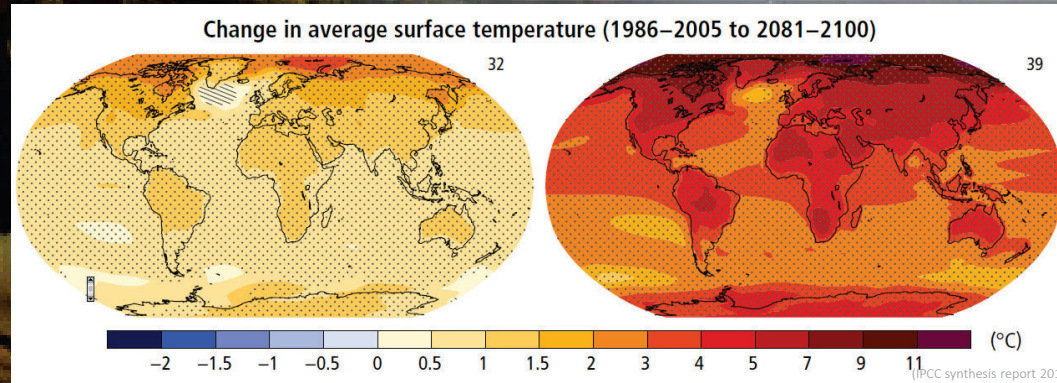


Global warming alters aquatic systems

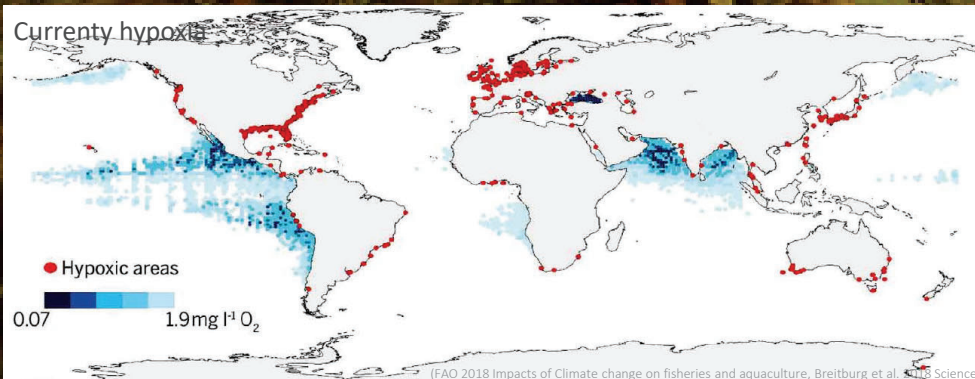
Warmer lakes & oceans



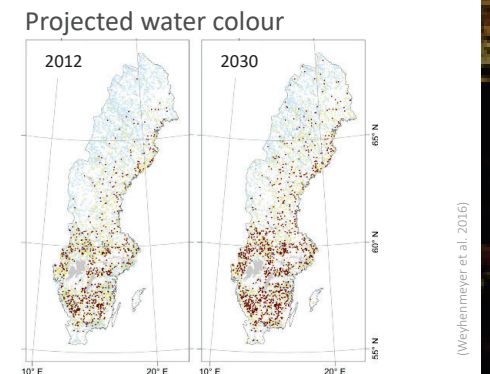
Warmer lakes & oceans



...with less oxygen



... & darker water

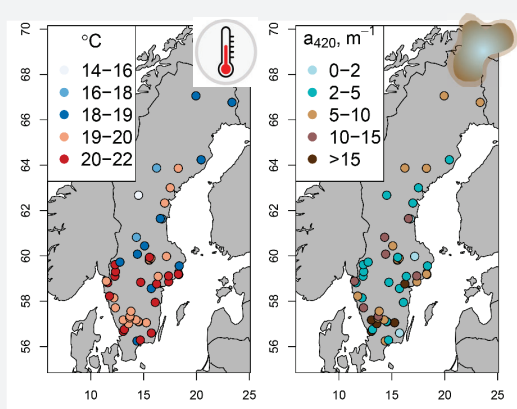




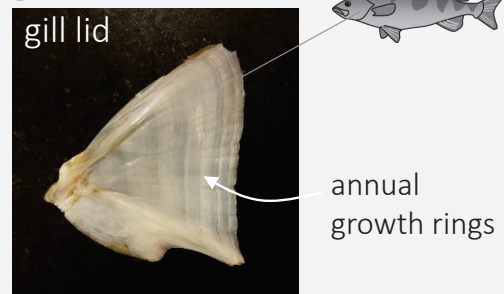
How do warmer and darker waters affect fish production & food web structure?

Warm & brown waters

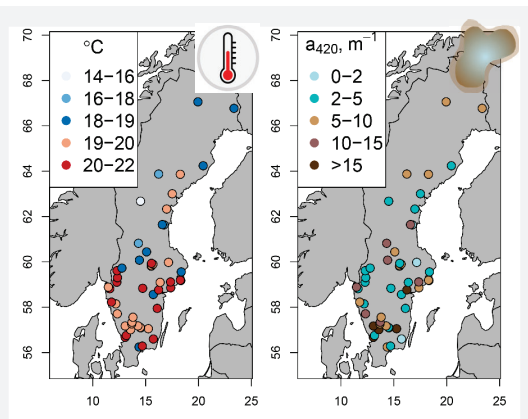
Combining large SLU monitoring data sets



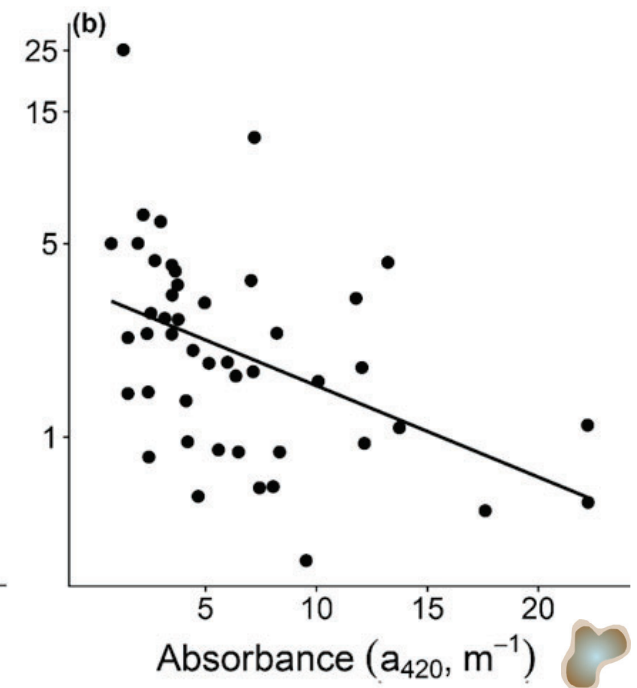
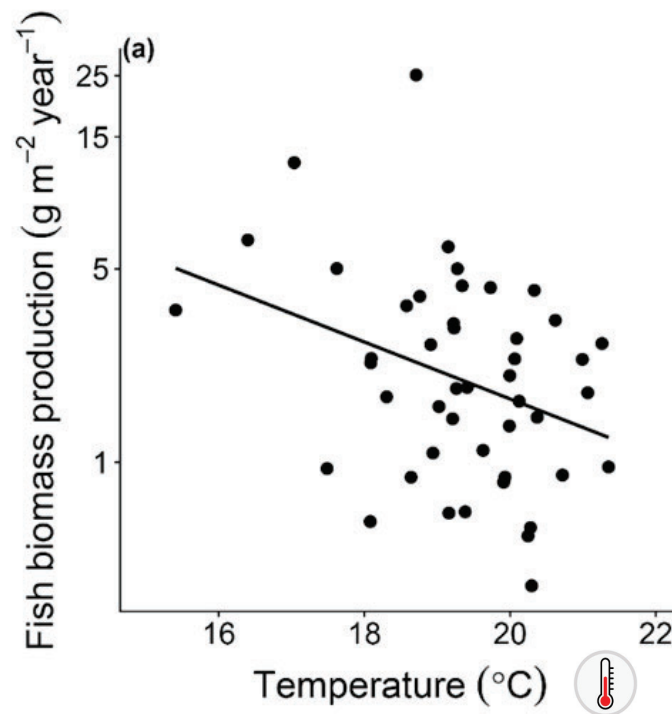
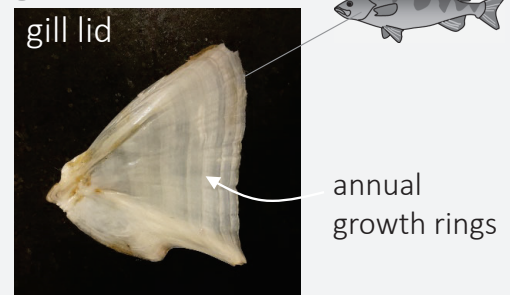
Fish production from survey fishing & growth measurements



Warm & brown waters have less fish production

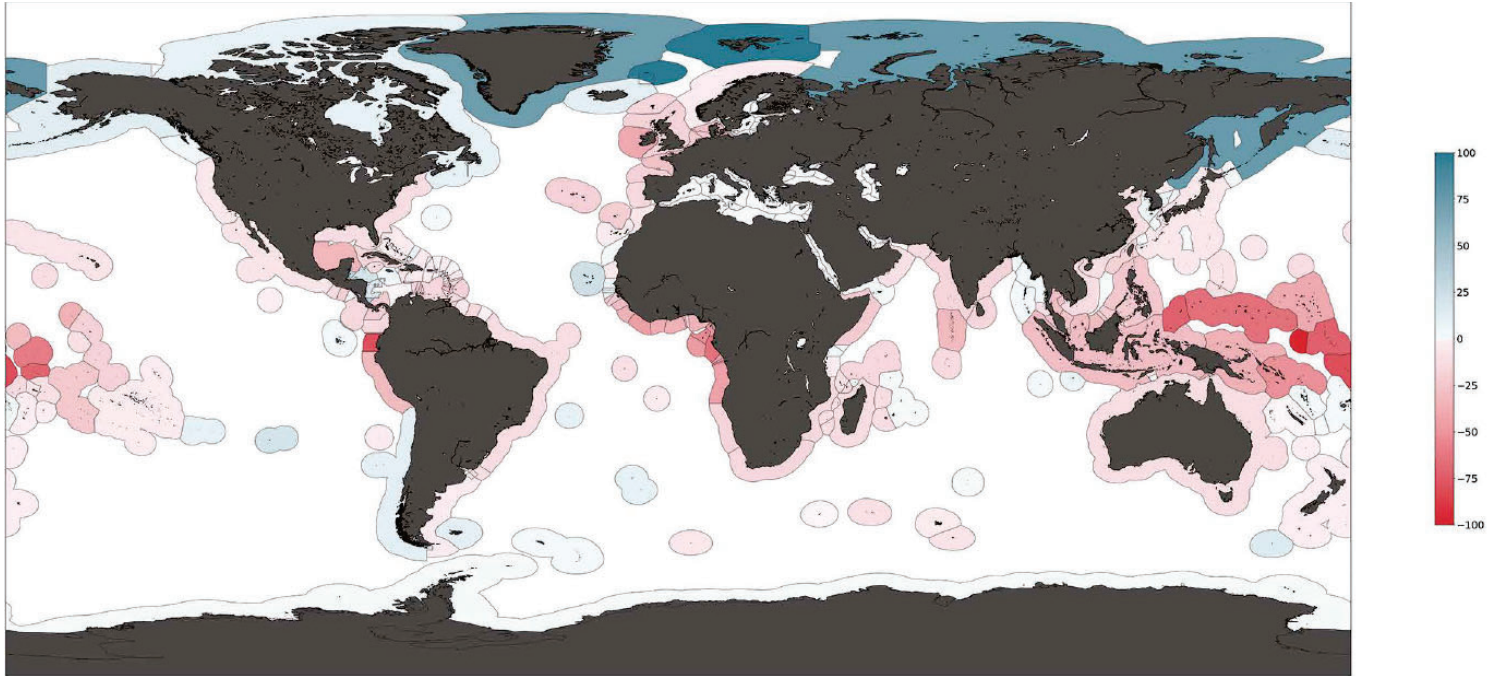


Fish production from survey fishing & growth measurements



Warming alters global wild fish production → risks to food security

Projected % change in maximum catch potential until 2050 under global warming (RCP8.5)

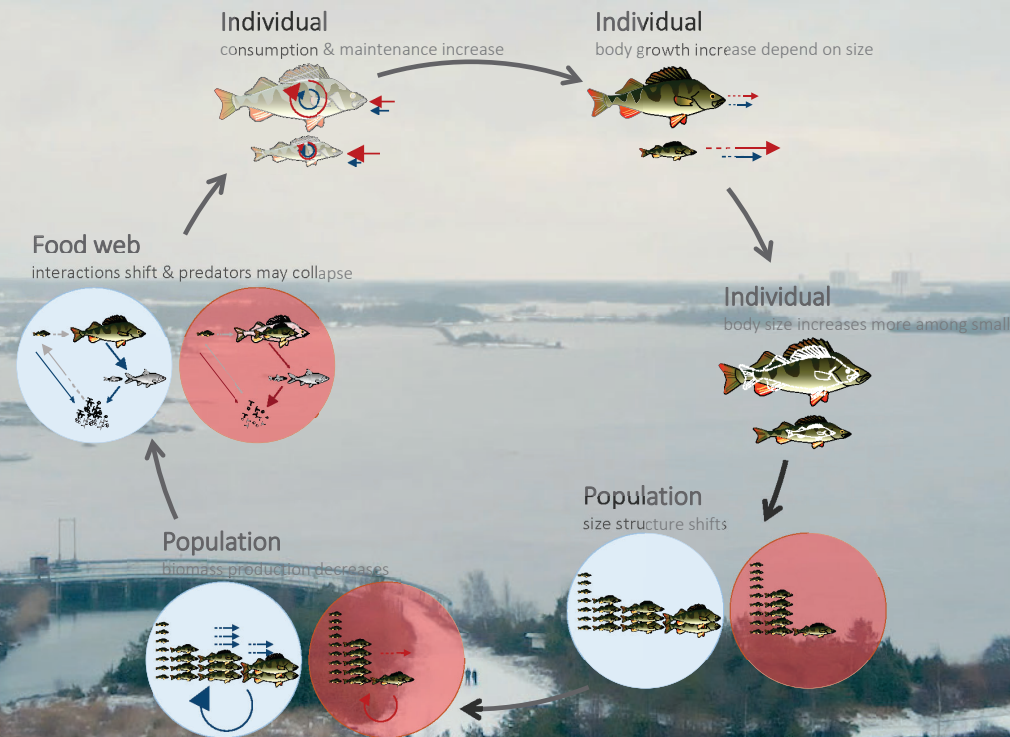


To find out why, we simulate climate change

field experiments & mathematical models



To find out why, we simulate climate change



Heated coastal bay "Biotest lake"

Outflow of warm water

Inflow warm water

mesocosms
simulating
climate change

mesocosms in
reference area

- *Ecosystem heated since 1980*
- *Both areas monitored since late 1970s*
- *Mesocosm experiments since 2014*

(access through cooperation with Forsmarks Kraftgrupp AB)

Photo: Fredrik Landfors



Fish growth responses to warming & browning?



Photo: Fredrik Landfors

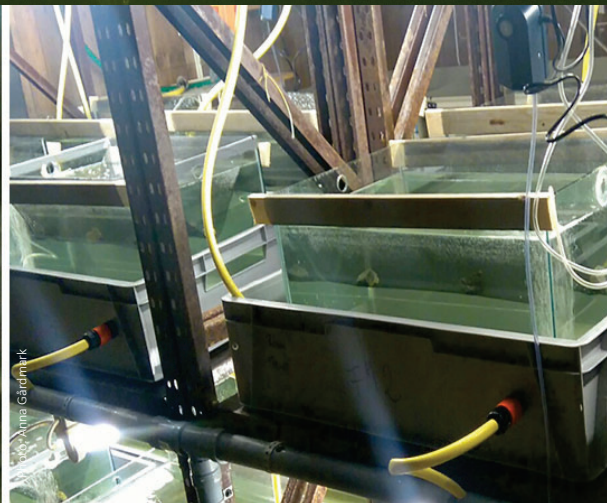


Photo: Anna Garumärk

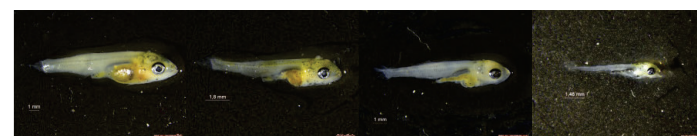
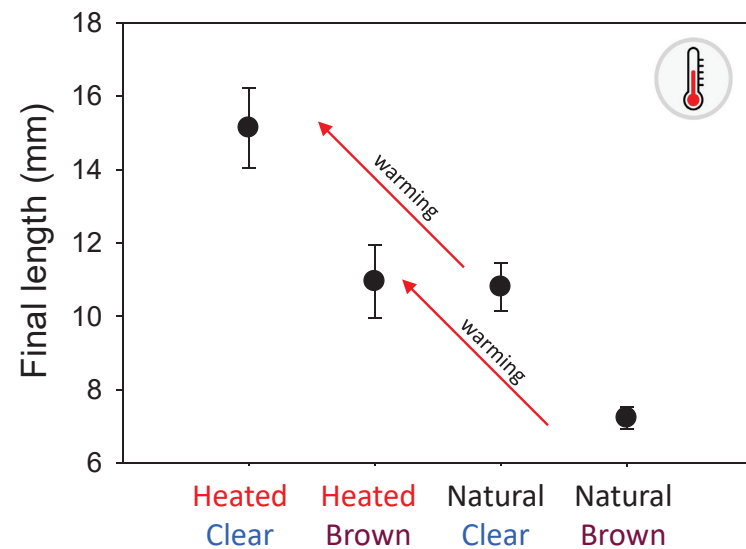
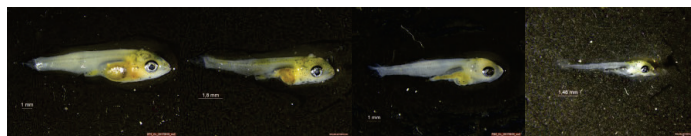
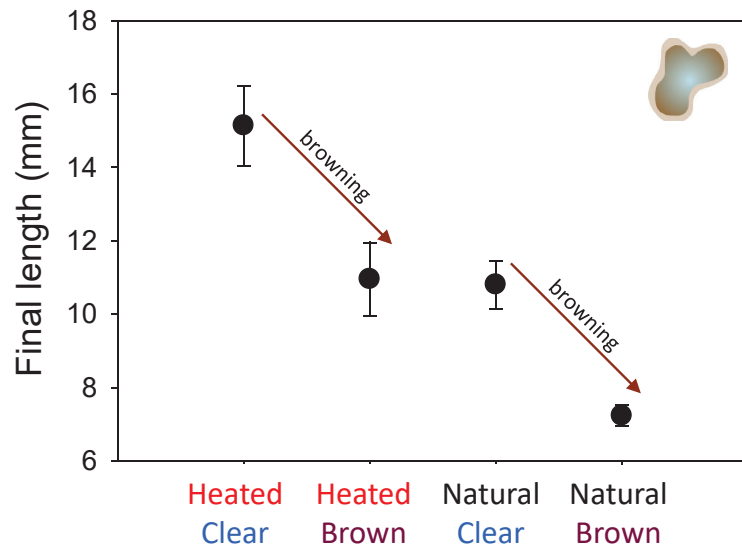
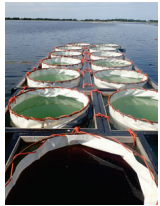
heated or
natural bay



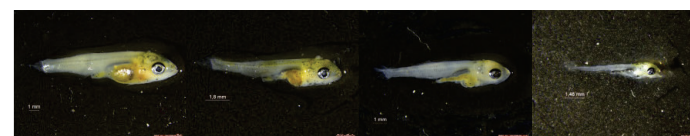
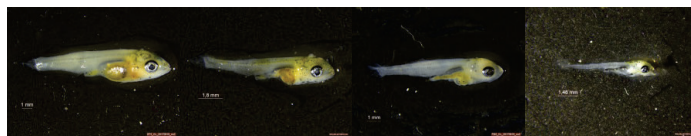
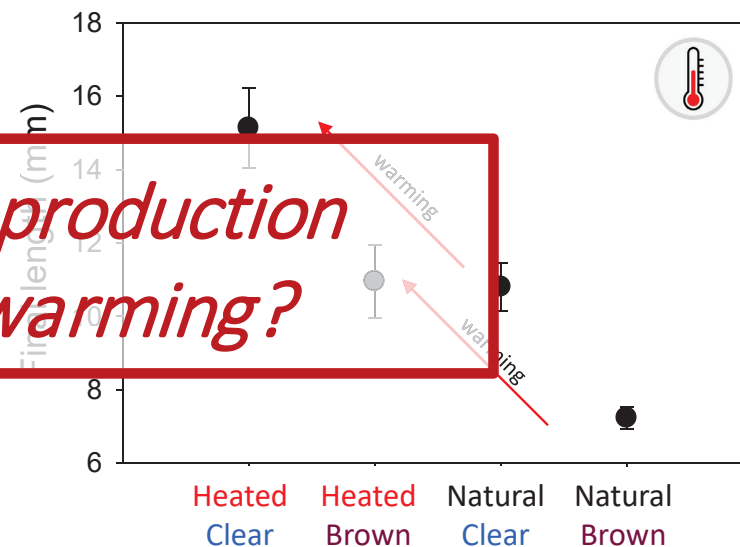
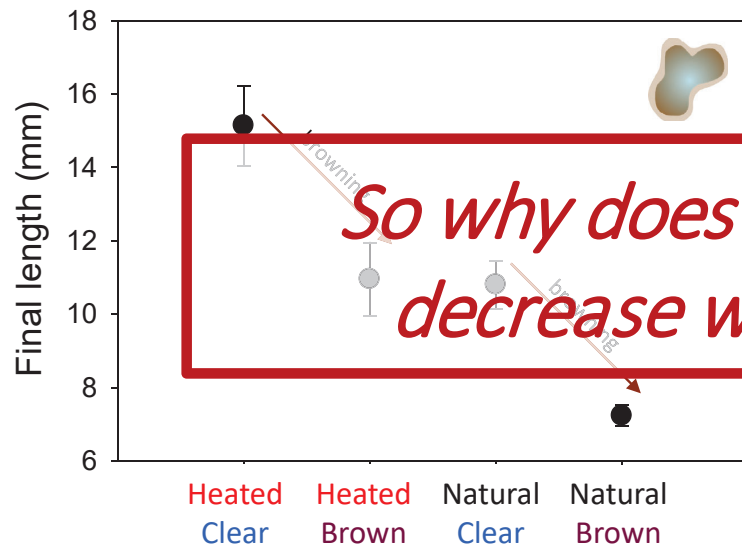
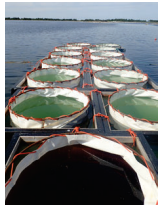
Photo: Helene Sjöqvist

shading
reducing visibility

Fish larvae growth decreases with browning, but *increases* with warming

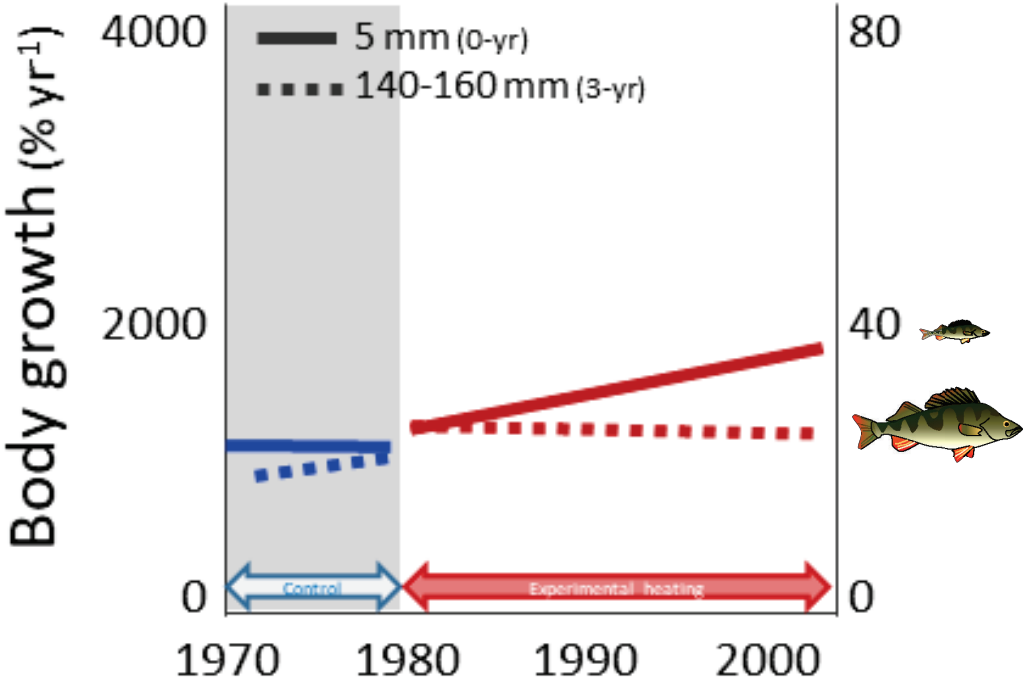


Fish larvae growth decreases with browning,
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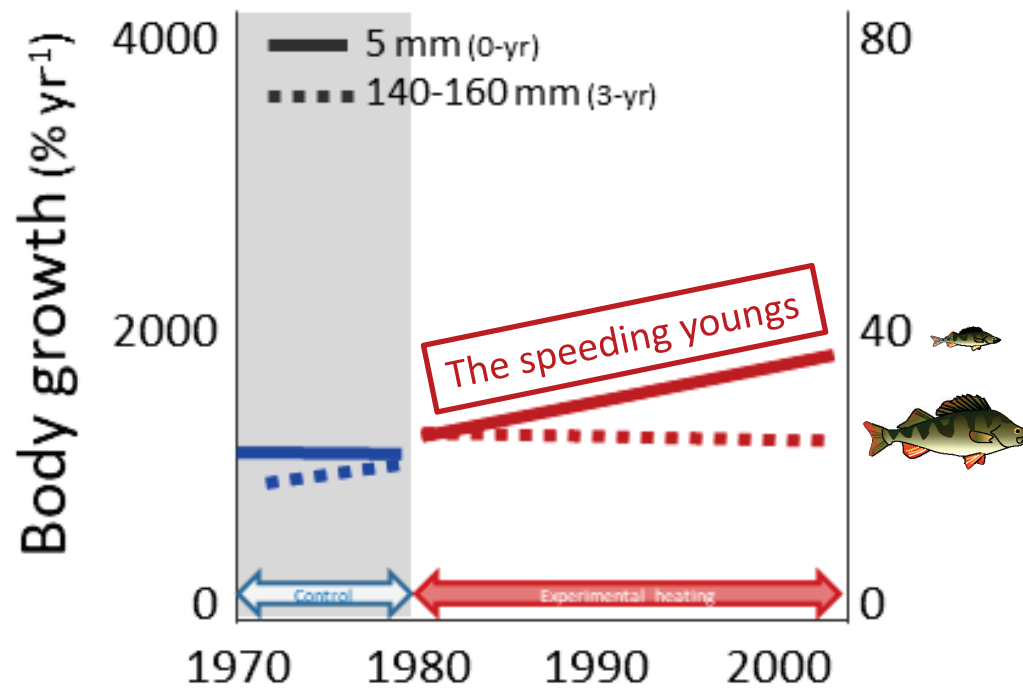


Small, but not large, perch grow faster with warming

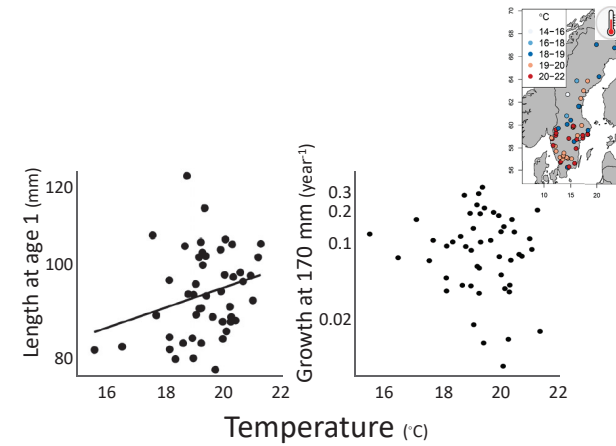
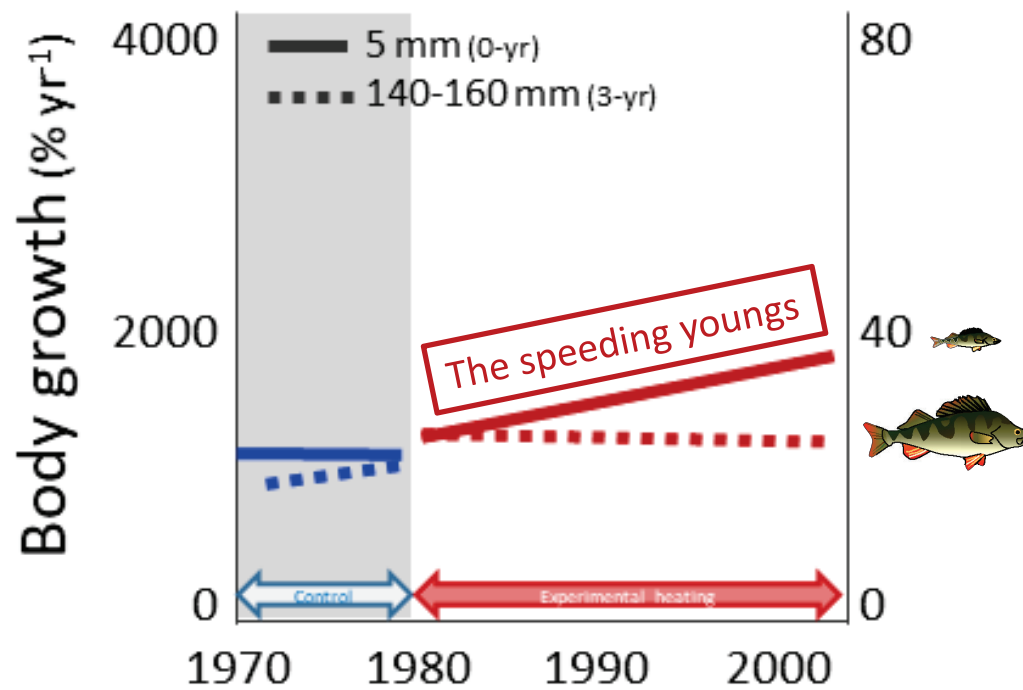
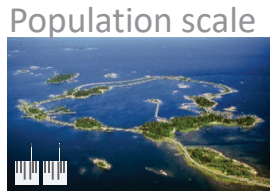
Population scale



Small, but not large, perch grow faster with warming

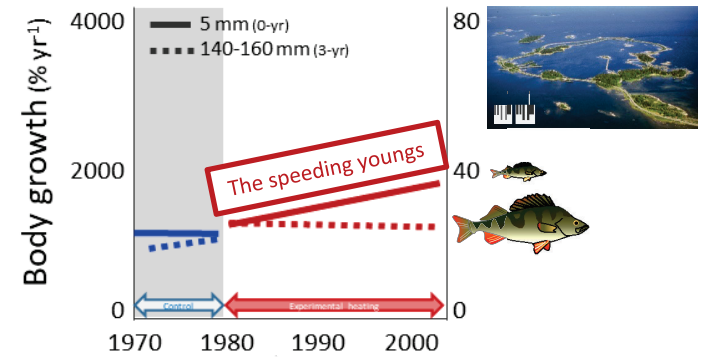
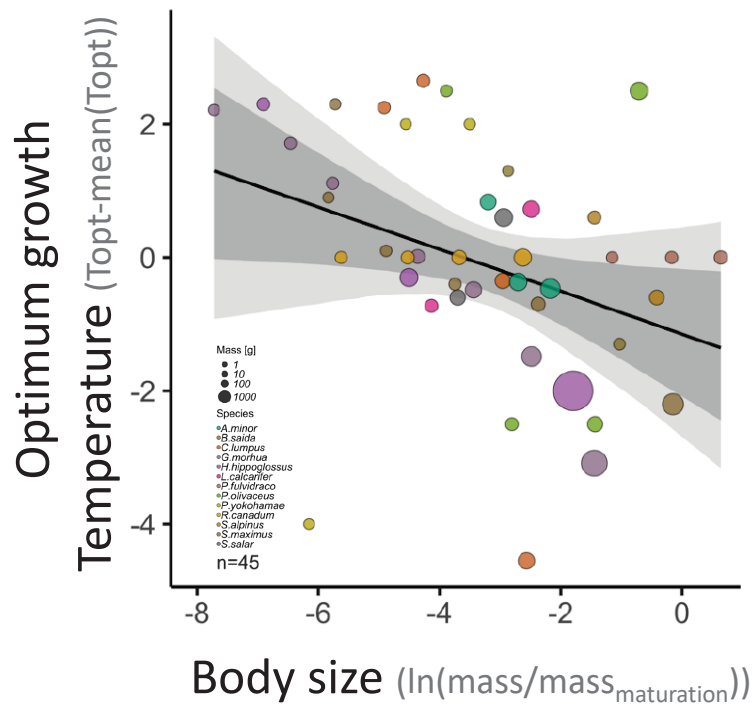


Small, but not large, perch grow faster with warming



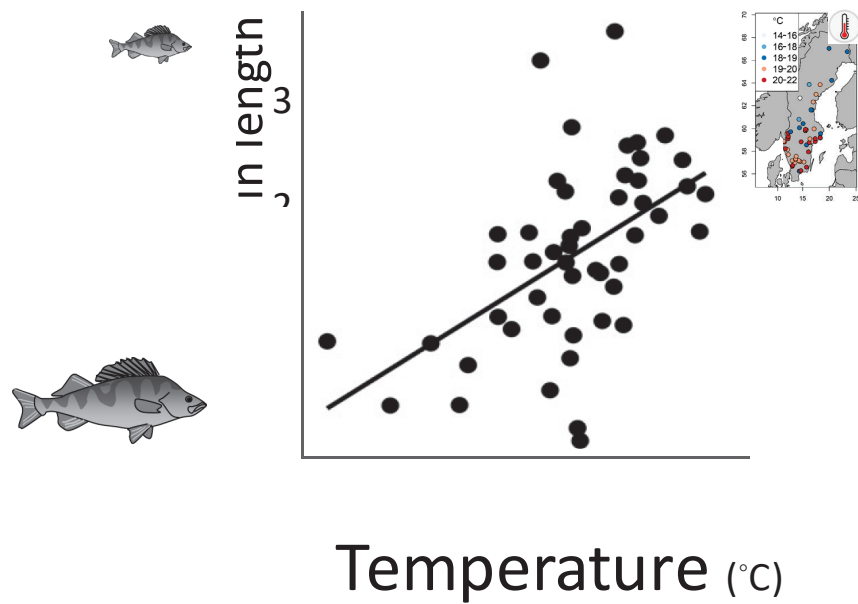
(Van Dorst et al. 2019 Global Change Biol, Huss et al. 2019 Global Change Biol)

...because optimum temperature for body growth declines *within species* with body size

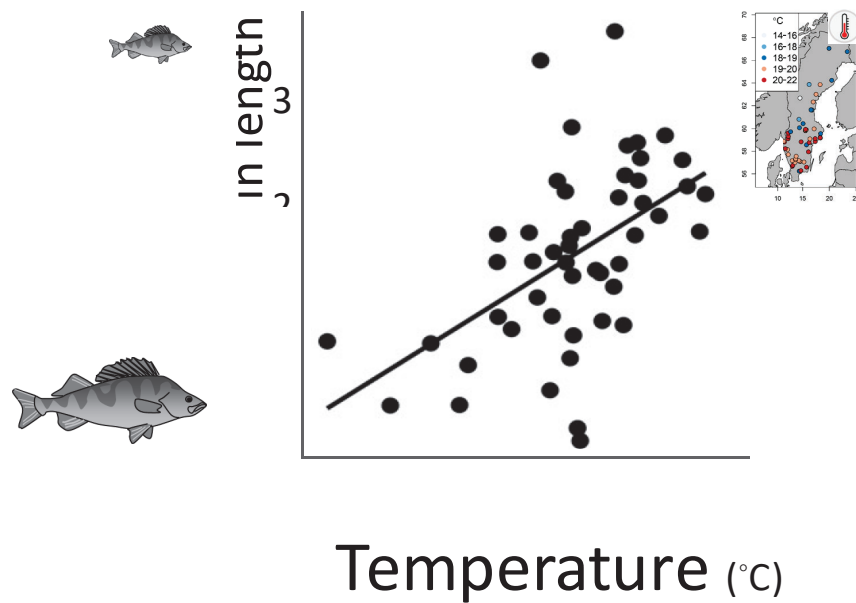


→ Warming shifts population size composition

Warming shifts population size composition



Warming shifts population size composition



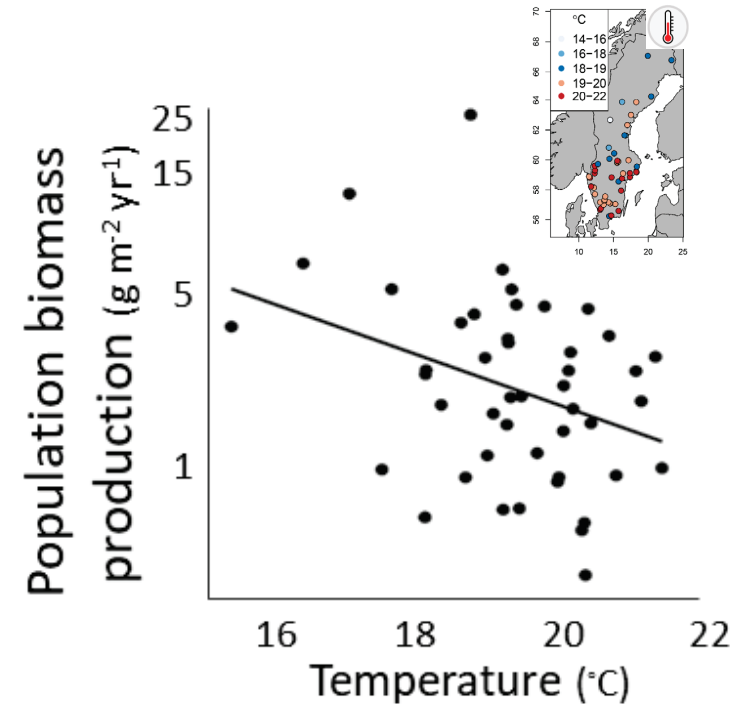
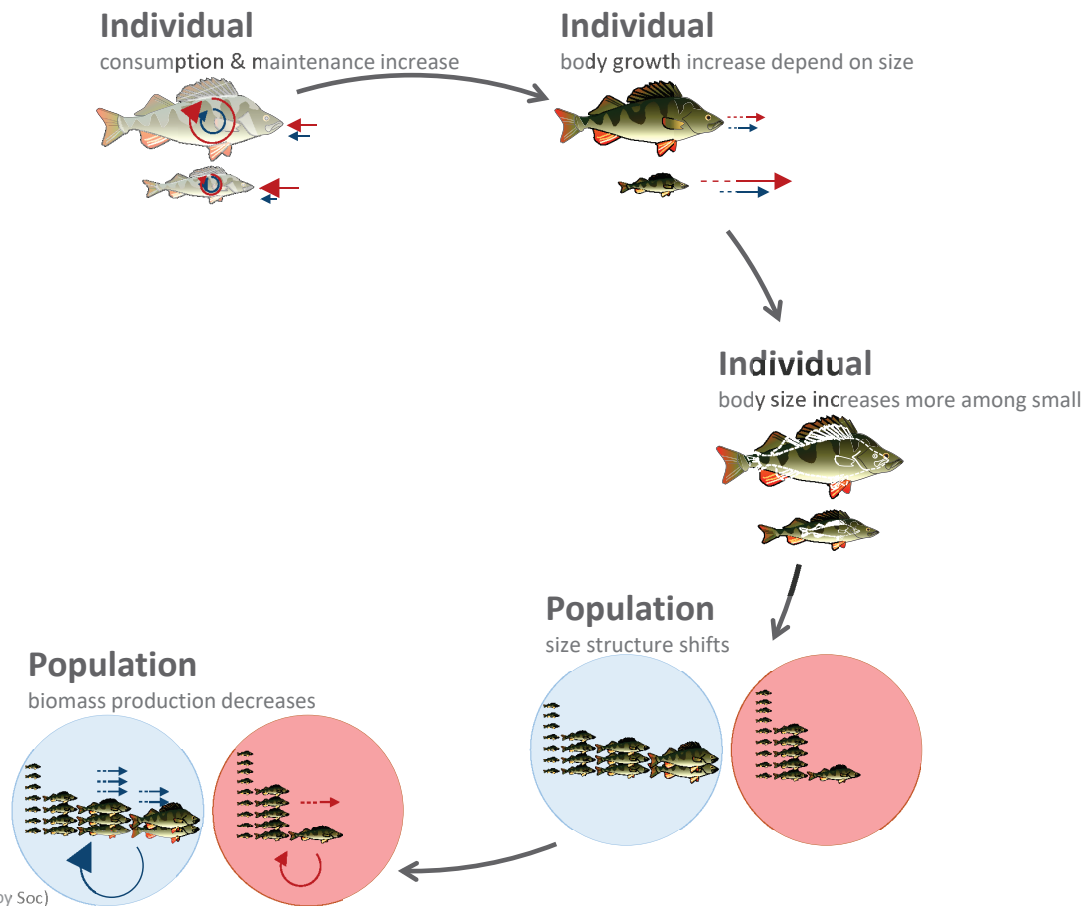
Dominance of small individuals

- in data & (often) models
- in fish & (often) zooplankton

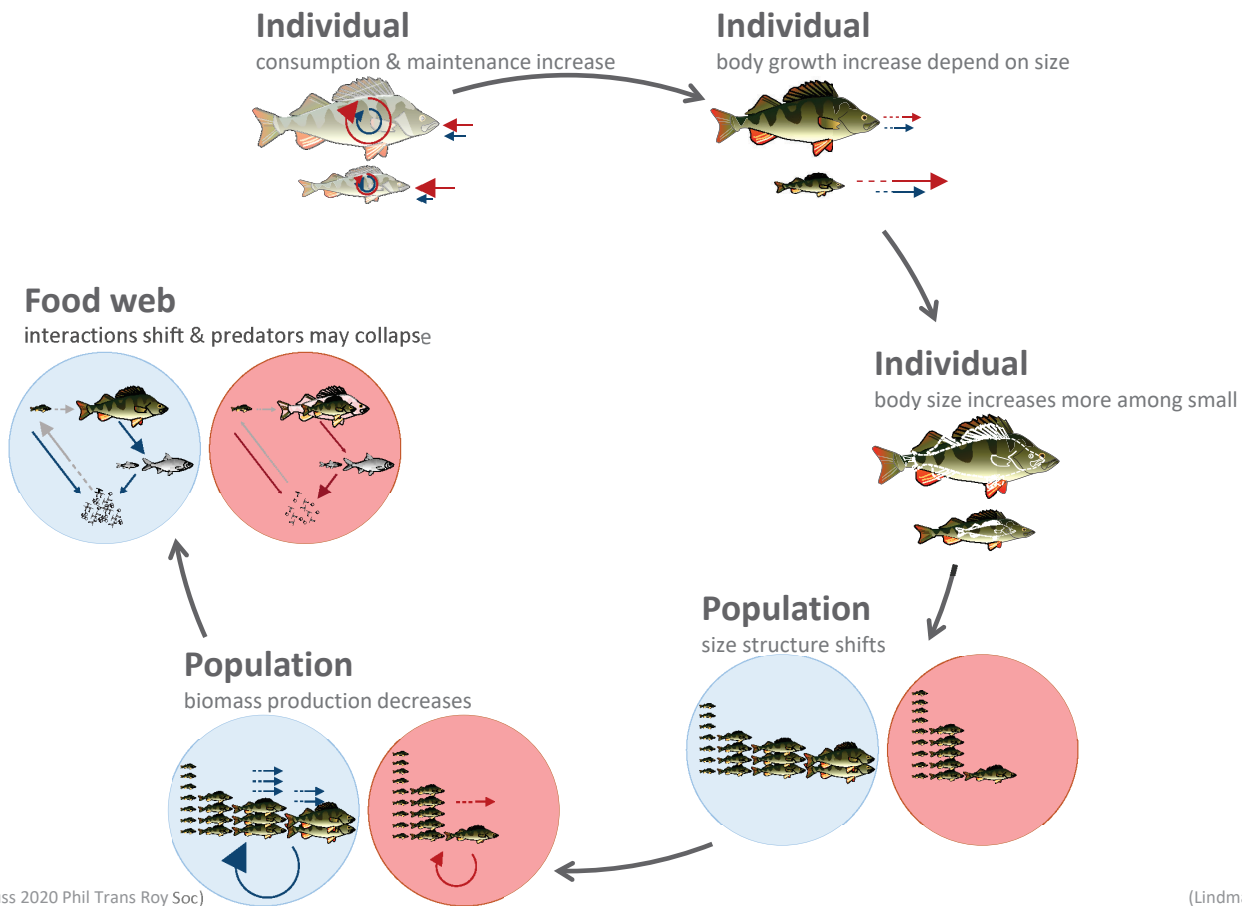
Fewer large individuals with no growth increase

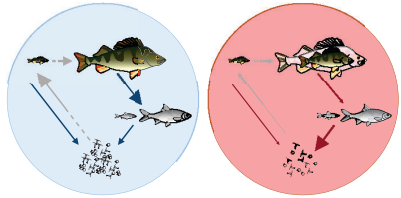
Fewer large individuals with no growth increase
→ lower fish production

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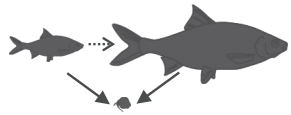


→ Warming alters food webs

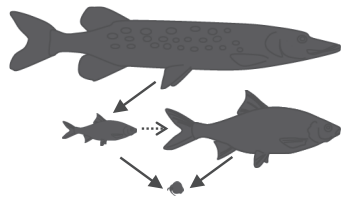




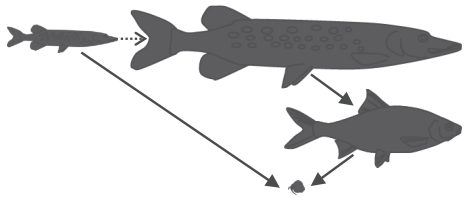
Warming alters food webs



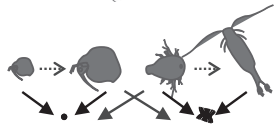
Consumer-resource systems



Food chains



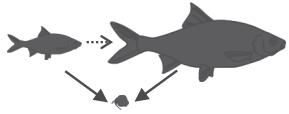
Intra-guild predation systems



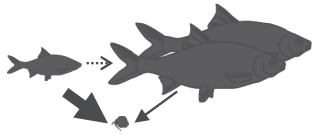
Complex food webs (competition)

Mathematical models linking individual-level physiological & ecological processes – that depend on temperature, body size & energy availability – to food web dynamics

Warming alters food webs



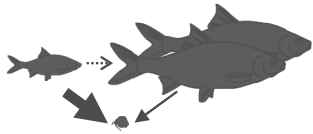
Warming alters food webs



shift in stage structure & in **bottlenecks** regulating dynamics

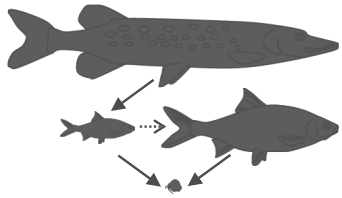
(Lindmark et al. 2019 Ecol Letters)

Warming alters food webs

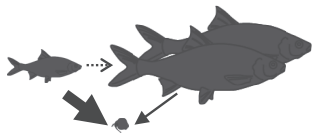


shift in stage structure & in **bottlenecks** regulating dynamics

(Lindmark et al. 2019 Ecol Letters)

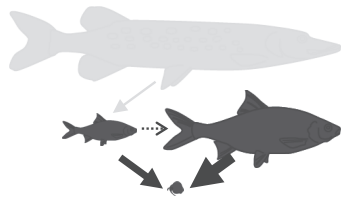


Warming alters food webs



shift in stage structure & in bottlenecks regulating dynamics

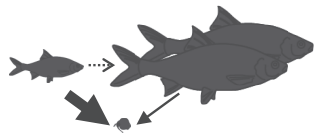
(Lindmark et al. 2019 Ecol Letters)



predator collapse, due to warming-induced resource depletion & increased energy demands, and shift in prey stage structure (emergent Allee effect)

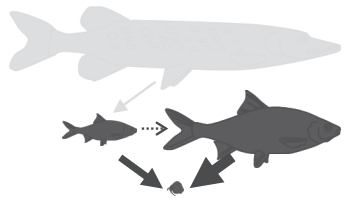
(Lindmark et al. 2019 Ecol Letters)

Warming alters food webs



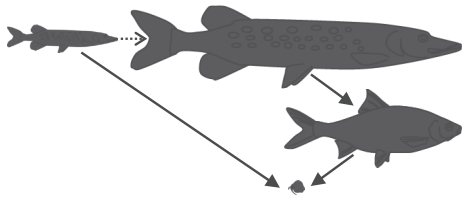
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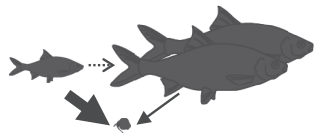


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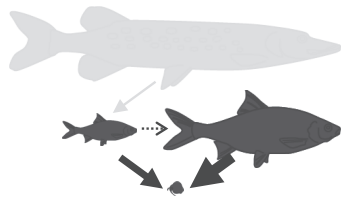


Warming alters food webs



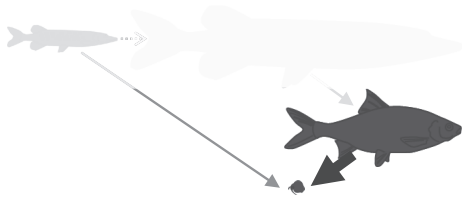
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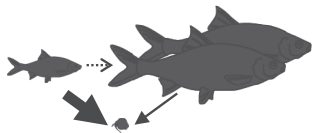
(Lindmark et al. 2019 Ecol Letters)



predator collapse, due to warming-induced loss of cultivation (top-down control of interspecific competition)

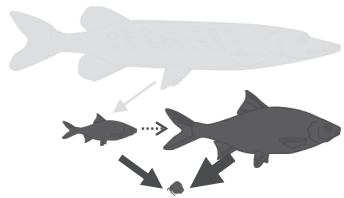
(Thunell et al., in revision for AmNat)

Warming alters food webs



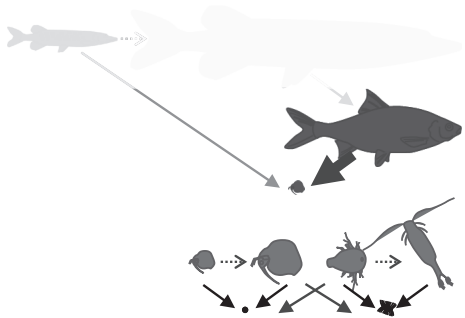
shift in stage structure & in bottlenecks regulating dynamics

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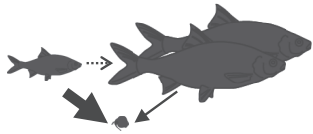
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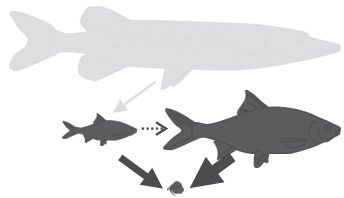
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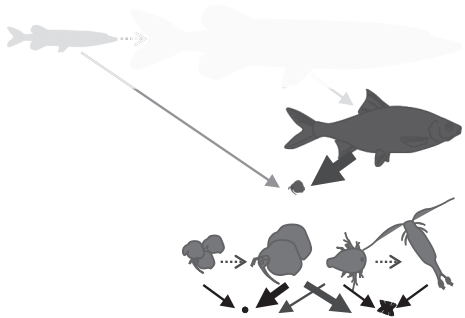
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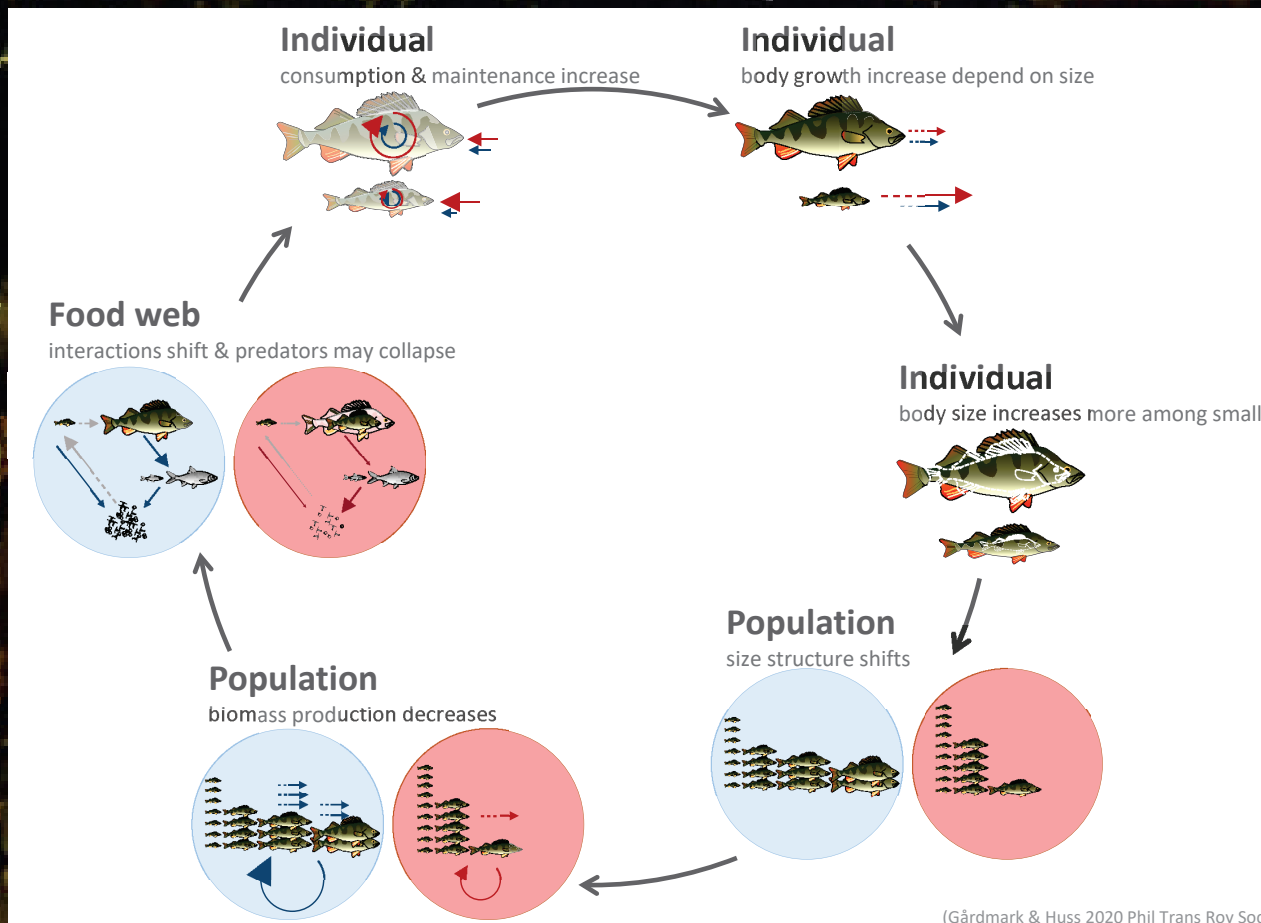
predator collapse, due to warming-induced loss of cultivation (top-down control of interspecific competition)

(Thunell et al., in revision for AmNat)

shift to dominance of small species (but large individuals)

(Uszko et al., in review in Ecol Letters)

Feedbacks determine effects of warming



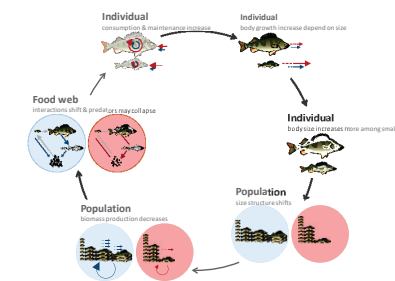
Great potential for SLU wide collaboration

Globally warming aquatic ecosystems

Great potential for SLU wide collaboration

Globally warming aquatic ecosystems

- risks to food security and food web functioning
- To understand the impacts we link processes in & among individuals to those in food webs



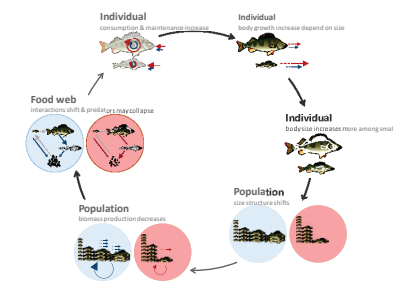
*Across types of organisms
& aquatic ecosystems*

Great potential for SLU wide collaboration

Globally warming aquatic ecosystems

- risks to food security and food web functioning
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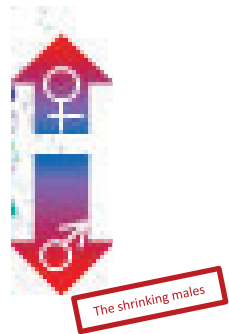
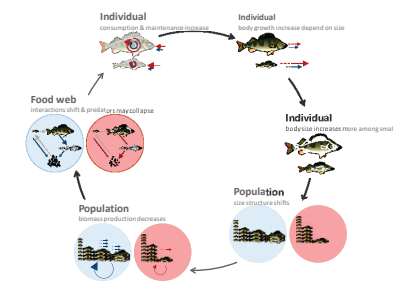
Different types of variation



Great potential for SLU wide collaboration

Globally warming aquatic ecosystems

- risks to food security and food web functioning
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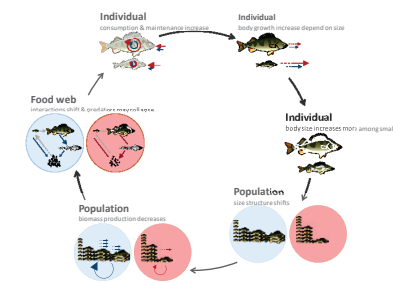


Great potential for SLU wide collaboration

Globally warming aquatic ecosystems

→ risks to food security and food web functioning

- To understand the impacts we link processes in & among individuals to those in food webs
- Multiple pressures beyond warming – deoxygenation, darkening, nutrient load, fishing



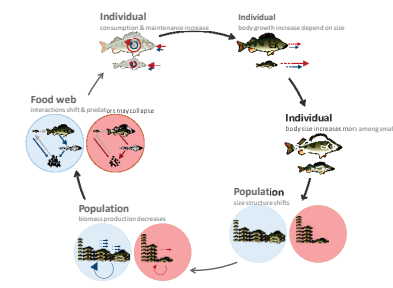
Pressures linked to land use, altering under warming

Great potential for SLU wide collaboration

Globally warming aquatic ecosystems

→ risks to food security and food web functioning

- To understand the impacts we link processes in & among individuals to those in food webs
- Multiple pressures beyond warming – deoxygenation, darkening, nutrient load, fishing
- *Ahead*: adaptation to climate change – in organisms (evolution) and society



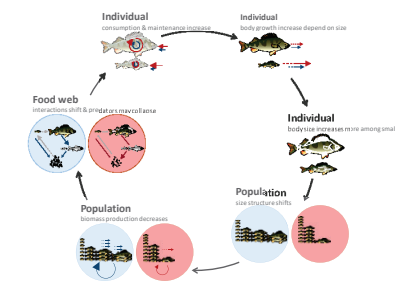
Informing societal adaptation to climate change

Great potential for SLU wide collaboration

Globally warming aquatic ecosystems

→ risks to food security and food web functioning

- To understand the impacts we link processes in & among individuals to those in food webs
- Multiple pressures beyond warming – deoxygenation, darkening, nutrient load, fishing
- *Ahead*: adaptation to climate change – in organisms (evolution) and society
- *e.g.*, How to adapt forest practices, land use & fishing to ensure fish production in warmer climates? Trade-offs across sectors (ecosystem services)?



Thanks!

Fantastic research group!

Viktor Thunell PhD-student

Jingyao Niu PhD-student

Aurélie Garnier Postdoc

Torbjörn Säterberg Postdoc

Elizabeth Duskey Guest postdoc

Olivia Bell MSc-student

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Senior Lecturer



Viktor Thunell
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Jingyao Niu
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Olivia Bell
MSc-student



Torbjörn
Säterberg
Postdoc



Aurélie
Garnier
Postdoc



Elizabeth
Duskey
Guest Postdoc

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SCIENCE AND
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