Arctic charr (Salvelinus alpinus) in a changing world: a review of individual and multiple pressures with an emphasis on climate warming

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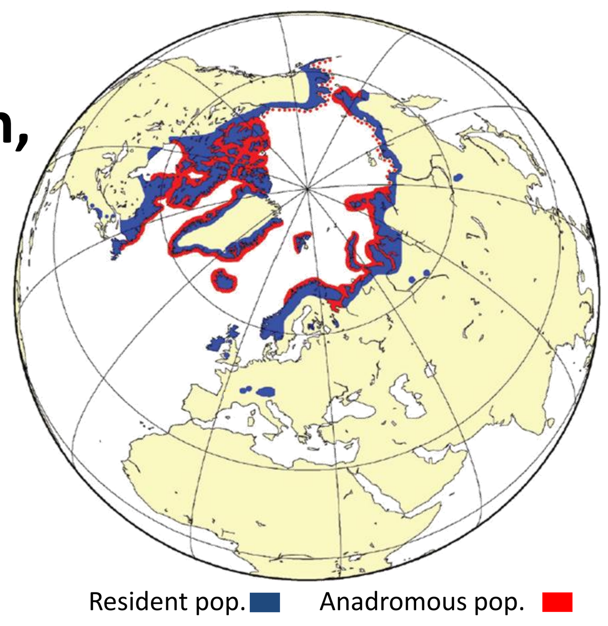
The Arctic charr (Ac):
- world's **most cold-adapted freshwater fish,**
- wide circumpolar distribution,
- strong **stenothermic requirements.**

Assumed to be particularly **vulnerable to increasing T°** in a warming climate as arctic and alpine regions are first concerned by heating.



After Svenning & Klemetsen, 2001

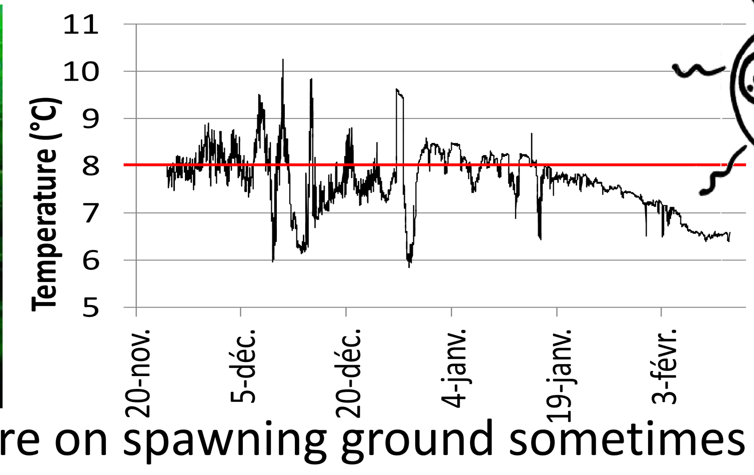
Pathways of action of climate change (CC)? Synergy with other stressors? Similar ways across distribution range? Adaptive potential facing CC?

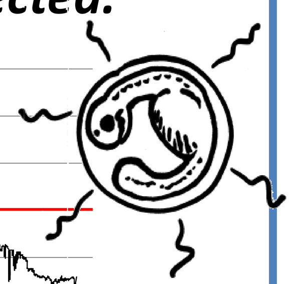
Direct effect of temperature increase

- Ovulation inhibited if T°>10-11°C during gonad maturation,
- Incubation imperiled if T°>8°C.

→ Under CC, warmer conditions should be deleterious, especially in southern populations through physiological mechanisms.

→ Numerous <u>cascading indirect impacts through other factors</u> expected.





In southern populations, temperature on spawning ground sometimes exceeds 8°C (here, in Lake Geneva, 40 m depth).

List – unfortunately incomplete! – of other stressors and indirect impacts of temperature increase

Oxygen depletion

Eggs suffer of low oxygen concentration in hypoxic deep layers and under fine sediments.

→ CC increases Ac metabolic rate and O_2 demand.

→ CC may deepen/promote thermal stratification in lakes and enhance bottom hypoxia.

→ CC may reinforce the symptoms of eutrophication or buffer positive effect of water quality recovery.

Trophic state and productivity changes

C, N and P input is a driver of ecological changes in Ac populations

Eutrophication caused population decrease in numerous lakes (oxygen depletion).

Increased prod. modifies biotic composition, and interactions, phenology and might favor residency *vs* anadromy of Ac.

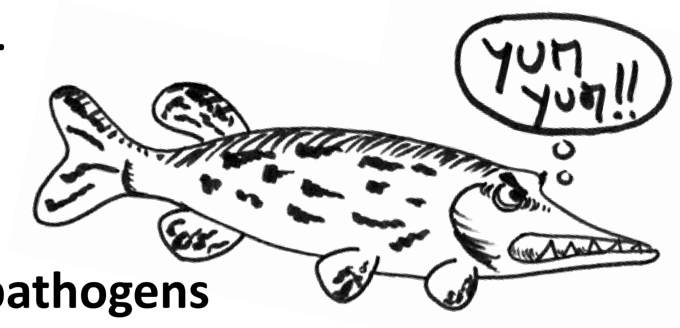
→ Although progress are made on nutrient input control, CC stimulates productivity and might increase symptoms of eutrophication.

Biotic interactions

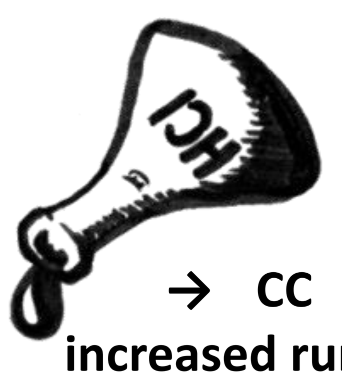
Ac naturally occupy relatively poor species lakes. Changes in biotic community are often deleterious.

→ CC may favour introduced or native predators or competitors, modify resource availability.

→ CC increases vulnerability to pathogens through pathogen prevalence or Ac sensitivity.



Acidification

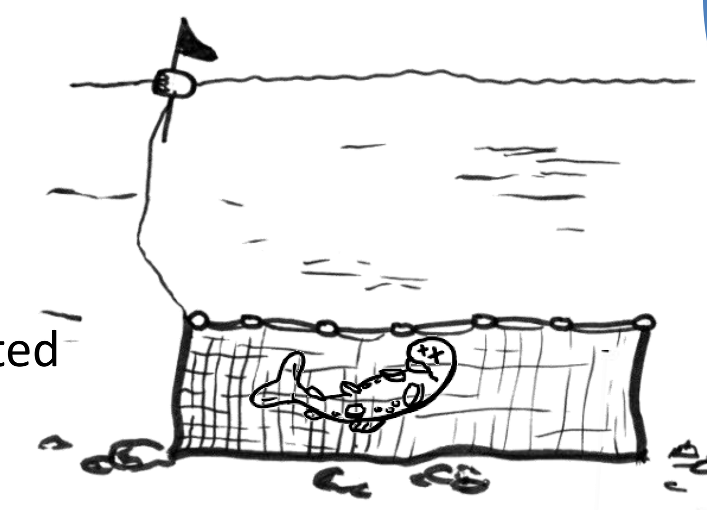


Low pH (<4.5-5) reduce embryos survival.

In northernmost countries, the majority of extinct populations were probably wiped out by acidification.

→ CC is supposed to influence pH through increased runoff and increased CO_2 loading.

Fishing, stocking and farming practices



Fishing during spawning contributed to population decline in the past

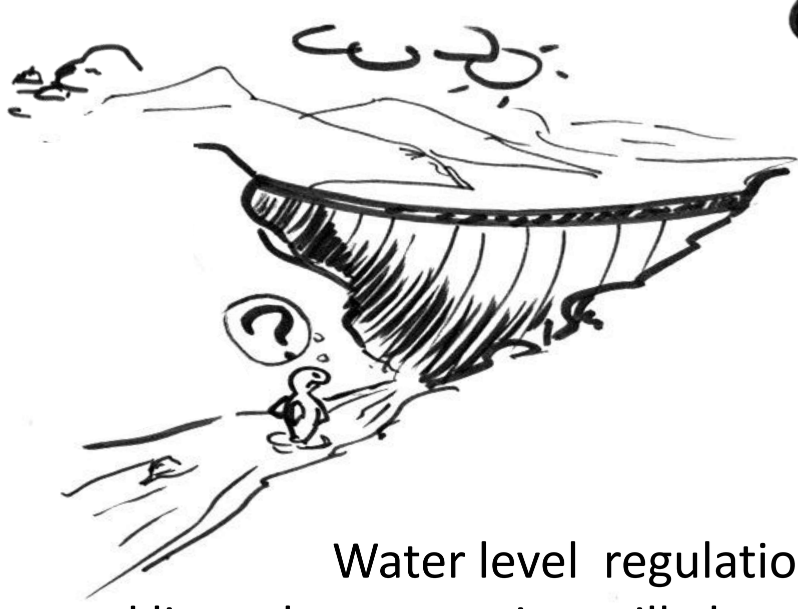
Impact of spawners fishing for supportive breeding largely unknown.

Stocking may decrease genetic diversity and produce fish misadapted to the wild.

Escaped fish from farms may impact wild Ac (genetic pollution, competition of farmed *vs* wild).

→ Not directly impacted by CC, but population loss increase the relative importance of these practices and their negative effects.

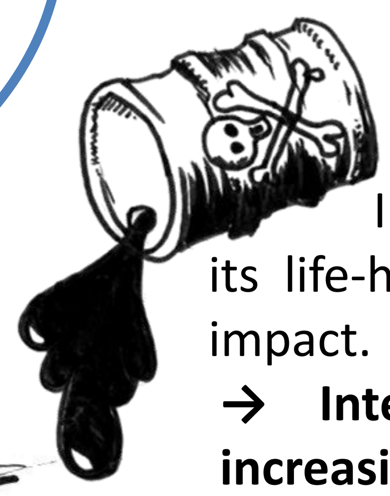
→ But most manageable pressure at short term.



Pollution

Impact of pollutants on Ac poorly investigated but its life-history make it a good candidate for pollutants impact.

→ Interaction with CC poorly investigated but increasing temperature is expected to improve pollutants ambient distribution and toxicity.



Hydrology and habitat modifications, connectivity loss

Water level regulation (hydropower) can expose spawning grounds to desiccation

Increased littoral zone erosion will also cause increased sedimentation rates in deeper water, affecting deeper spawning sites.

Dams, water quality alteration or hydrological changes increase connectivity disruption.

→ CC will impact most hydrological variables and water management and withdrawal.

Conclusion

- Most stressors supposed to be **synergistically influenced by CC** through synergetic or cascading effects.
- **Evidence and quantification are still scarce** for most stressors.
- Stressors' influence and CC impact is **context dependent:**
  - → direct impact likely mainly of concern for southern pop,
  - → biotic interactions changes impact likely dominate in northern pop.
- Ranking stressors remains hazardous yet due to gap in knowledge.
- Actually, fishing, stocking and farming practices are the most **manageable levers of action** at a small timescale.

Perspectives

- Continue to evaluate the impact of stressors and interactions on life-history, population dynamics and genetics.
- Rank stressors (needed for management).
- Assess the spatial variability of response to stressors and local adaptations. Experimental approach needed.
- Evaluate the adaptive potential facing various factors (including T° effect on physiology).

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