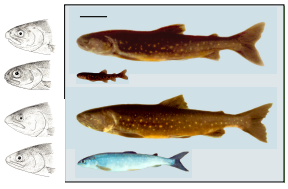
Patterns of evolution in a polymorphic fish: a challenge for conservation and management?

Pamela J. Woods [1 2], Skúli Skúlason [2], Bjarni K. Kristjánsson [2], Sigurður Snorrason [1]

(1)University of Iceland, Faculty of Life and Environmental Sciences, pamelajwoods@gmail.com, (2)Hólar University College, Department of Aquaculture and Fish Biology.



Introduction

•Heavy emphasis is placed on the maintenance of biodiversity in conservation efforts.

•However, the processes that yield these patterns are rarely considered vulnerable.

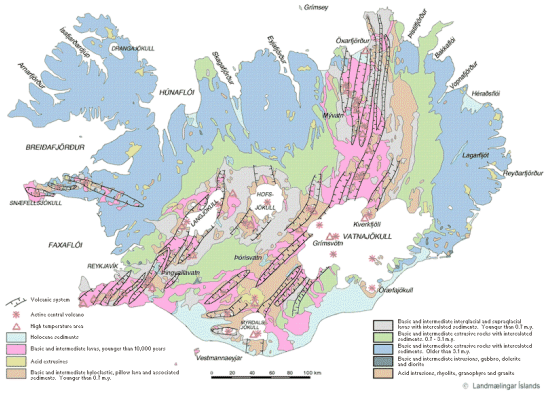
•Resource polymorphism, such as in Arctic charr (*Salvelinus alpinus*), can give rise to sympatric morphs and species. Morphs can differ in body size, diet, or morphology, but the degree of divergence may depend on the system.

•To understand which ecological conditions are important for species divergence, many populations at different stages of divergence were analyzed across systems of various ecological conditions.

•The database from Ecological Survey of Icelandic Lakes Project yields a rare opportunity to conduct this study on a large geographic scale.

Here we related patterns of invertebrate abundance from stone habitats to ecological data across lakes.

These patterns were related to fish population data, including size, morphology, and brown trout abundance.



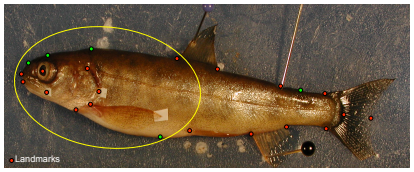
Because Iceland lies on the mid-Atlantic ridge, aquatic habitats are diverse in geological age and hydrology of the region.

Diversity of Icelandic freshwater habitats is influenced by glacial melt (left) and porous lava bedrock (middle). Lava is a complex habitat for both invertebrates and fish (right).

Results

•Patterns in **stone habitat invertebrate abundance** in relation to **limnological data and stone invertebrate diversity indices** were highly significant in a canonical correspondence analysis (P = 0.005, 199 permutations, N=50 lakes – Figure 1A).

•**Arctic charr population data** were related to these invertebrate communities using multiple regressions over the first two axes CCA1 & CCA2 (P≤ 0.05, N=40 lakes – Figure 1B).



•Morphology of fish was analyzed using geometric morphometric relative warp analyses of 1) all 22 landmarks for body relative warps (BRWs) and 2) the anterior encircled 12 landmarks for head relative warps (HRWs).

Legend

SMD – Margalef's D
SH – Shannon Index
NO3 - Nitrate
ST – Summer Air Temp (Mean May – Sept)
TOC – Tot. Org. Carbon
SiO2 – Silicon Dioxide
ALT – Altitude
MAXD – Max. Depth
TOP – Tot. Org. Phosphate
SA – Surface Area
FE – Iron
Hyz – Hydrozoa
Nem – Nematoda
Lym – *Lymnaea pereger*
Pis – *Pisidium* spp.
Aeo – Aeolosomatidae
Sty – *Stylaria lachstris*
Nai – Naididae
Tub – Tubificidae
Lum – Lumbriculidae
Enc – Enchytraidae
Hir – Hirudinea
Col – Coleoptera
Ost – Ostracoda
Ple – Plecoptera
Apa – *Apatania* spp.
Hyc – *Hydracarina* spp.
Lim – *Limnephilus* spp.
Pot – *Potamophylax* spp.
Gam – *Gammarus duebeni*
OrL – Orthocladiinae larvae
ChL – Chironiminae larvae
TaL – Tanypodinae larvae
OrP – Orthocladiinae pupae
ChP – Chironomina pupae
TaP – Tanypodinae pupae
ChA – Chironomidae adults
Fly – Other flies
Length – Mean Length
Weight – Mean Weight
BTA – Brown Trout CPUE
HRW1 – Mean Head Shape
BRW3 – Mean Body Shape

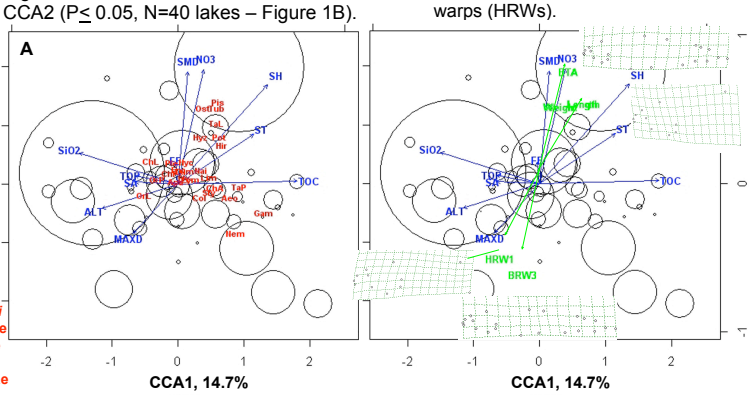


Figure 1: A - Canonical correspond… invertebrate abundances constrained by ecological data. Circles represent the CCA1 and CCA2 scores for each lake, with the radius proportional to the total abundance of rocky bottom invertebrates. **B - Multiple regression relationships of Arctic charr population data and morphological variables with the ordination of invertebrate communities.** Vectors represent the relative strength (length) and nature (direction) of the best-fit plane. Deformation grids show morphology of Arctic charr at the extremes for positive values of HRW1 and BRW3 (bottom left, B) and negative values (upper right, B).

Conclusion

•More diverse invertebrate assemblages occur in shallow lowland lakes, where summer temperature is higher and lakes have increased amount of nitrates and iron.

•Communities of these lakes are characterized by higher abundances of bivalves *Pisidium* spp., ostracods, tubificid worms, tanypodin (chironomid) larvae, *Potamophylax* caddisfly larvae, and leaches (Hirudinea).

•In these locations, brown trout were more abundant and Arctic charr were longer and heavier with deeper bodies (BRW1) and relatively shorter heads (HRW1).

Because these lakes tend to have larger and more abundant fish, fishing is likely to be common. These lakes should be monitored for competition between Arctic charr and brown trout and the effects of fishing on population dynamics and intraspecific fish diversity.

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