Multi-decade analysis revealed the worsening of growth conditions of a generalist cyprinid fish in a temperate ecosystem

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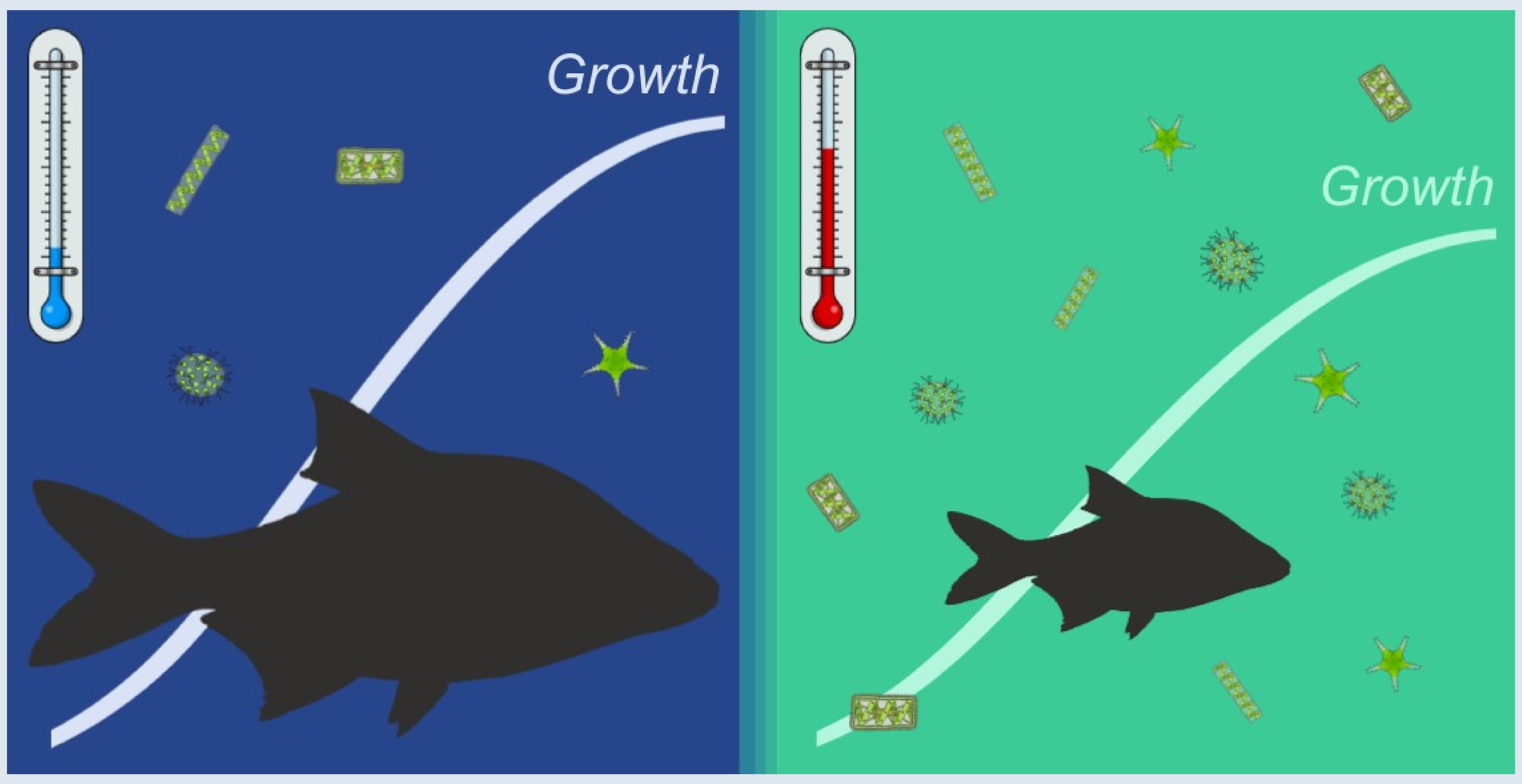
Graphical abstract



Introduction

- Long-term data
  - Detect ecosystem changes and population trends.
  - Population reaction to stressors.
- Climate change
  - Temperature is a major driver of several physiological, behavioral and phenological characteristics of ectotherms.
- Environmental management
  - Human direct actions can have significant impacts on several ecological parameters.

Material & methods

- Study site (Fig. 1)
  - Římov reservoir (South Bohemia, Czechia).
- Model species (Fig. 2)
  - Bream (*Abramis brama*).
- Fish length back-calculations
  - From bream scales *annulli.*
  - Fraser-Lee back-calculation model.
  - Growth model fitting (Lester's bi-phasic).
- Growth increments
  - Lentgh at $\text{Age}_{(i)}$ – Length at $\text{Age}_{(i\text{-}1)}$
- Statistical modelling (R software)
  - Data scaling, centering and log transformed.
  - Linear mixed-effects model.

Figure 1. Aerial photograph of the Římov reservoir, Czechia.

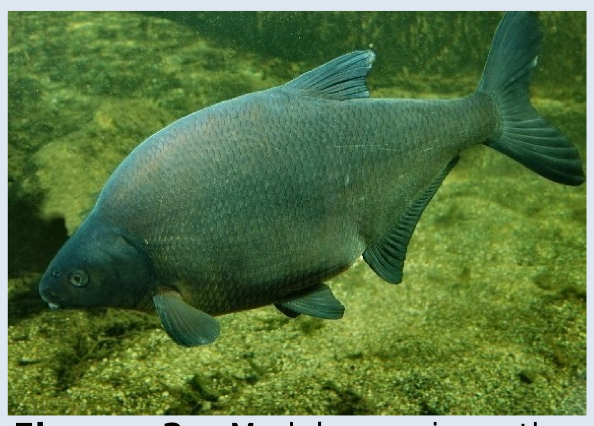


Figure 2. Model species, the bream (*Abramis brama*).

Results

- Eight out of ten descriptors were significantly varying through time (Fig. 3).
  - Only cladocerans and water level did not change through time.
  - Temperature was the only variable that increased through time.

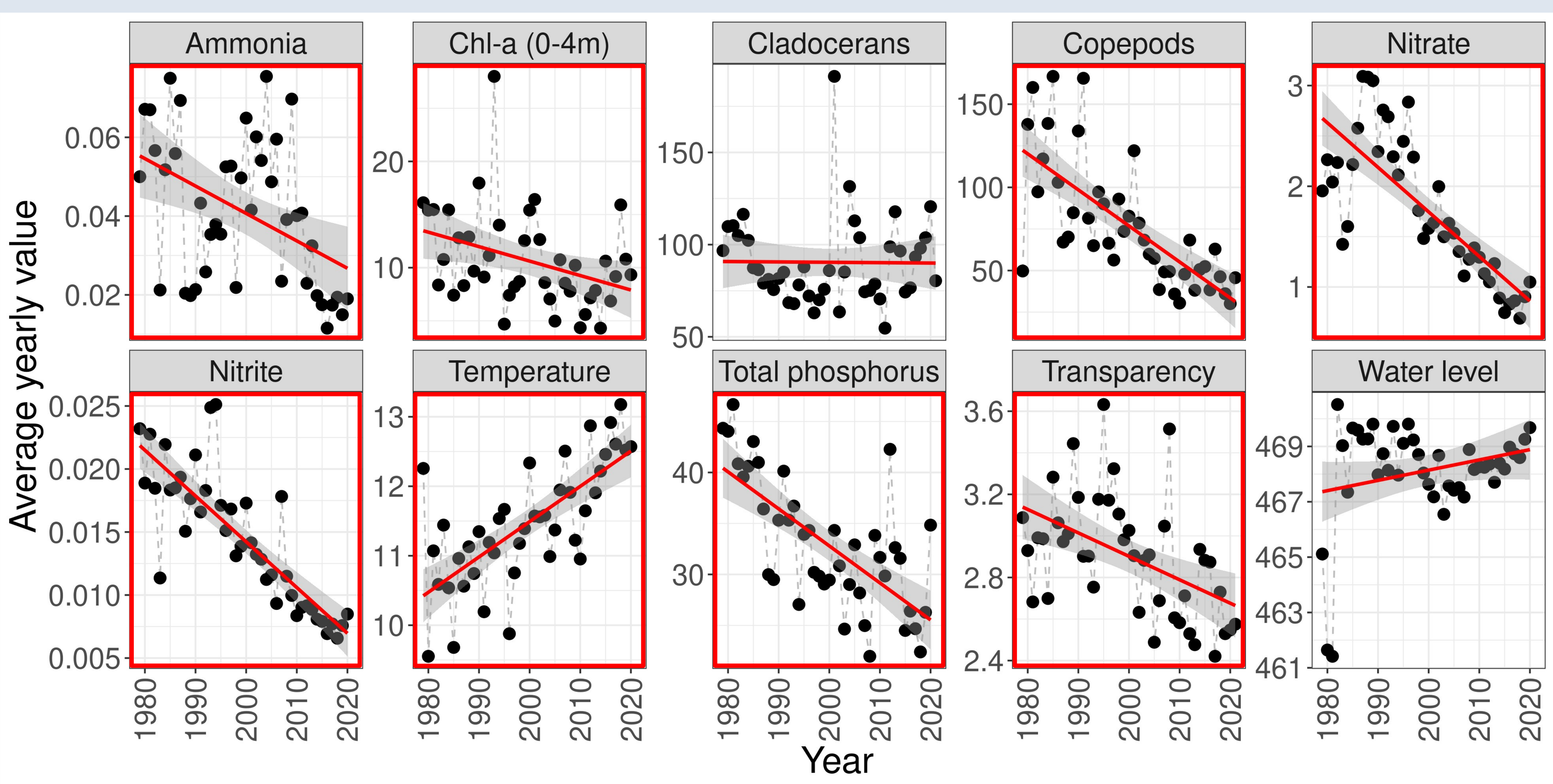


Figure 3. Yearly averages and trend line of the ten environmental descriptors collected in Římov reservoir, Czechia. Variables with significant differences through time are marked with thick red borders on the plot.

Results

- Inter-annual variation in bream growth trajectories (Fig. 4A).
  - Poorer performance after 2010's.
- Decreasing trend on the K coefficient extracted from the Lester's bi-phasic growth model (Fig. 4B).
  - The conditions were much better up to the beginning of the 1990's.

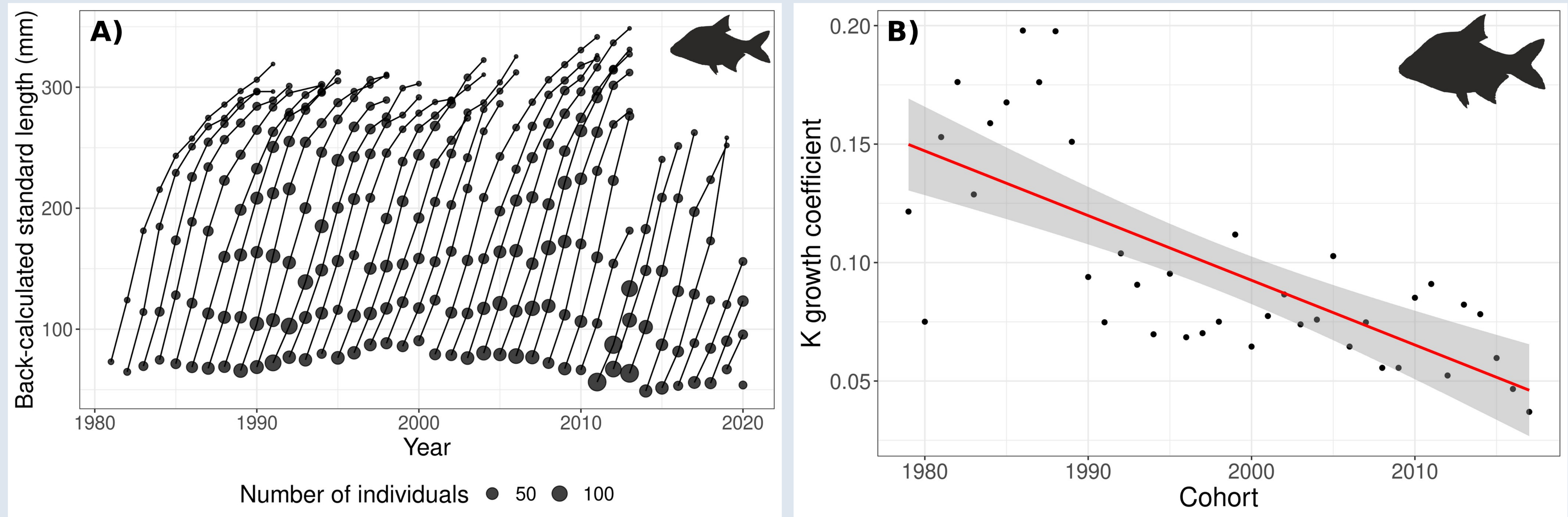


Figure 4. A) Average growth trajectories of different bream (*Abramis brama*) cohorts through four decades in Římov reservoir, Czechia. Data points in the graph were filtered to show only entries with more than three individuals in a specific age group of a given cohort. B) Temporal shift in the bream growth from Římov reservoir (Czechia). The values refer to the K coefficient extracted from the Lester's bi-phasic growth curve fit for each cohort.

- The stepwise selection on the full model indicated that age, chlorophyll and temperature were significantly affecting the bream somatic growth (Table 1).

Table 1. Summary table with the results of the linear-mixed effects model exploring the effects of intrinsic (age, cohort and year) and extrinsic drivers (Chl- α (0-4m) and temperature) on the somatic growth of the bream (*Abramis brama*) in the Římov reservoir, Czechia.

Predictors	Estimates	CI	Statistic	p
Fixed effects				
Intercept	3.75	3.68 – 3.82	101.73	**<0.001**
Age	-0.41	-0.60 – -0.23	-4.30	**<0.001**
Chl-a	-0.09	-0.17 – -0.01	-2.12	**<0.05**
Temperature	-1.24	-1.73 – -0.75	-4.93	**<0.001**
Random effects				
σ^2			0.17	
τ_{00} cohort			0.03	
$\tau_{00\ year}$			0.02	
τ_{00} cohort x Age			0.22	
τ_{00} year x Age			0.16	
ρ_{01} cohort			0.84	
ρ_{01} year			0.83	
ICC			0.56	
N_{cohort}			41	
N_{year}			41	
Observations			9153	
Marginal R^2/Conditional R^2			0.17 / 0.64	

Conclusions

- Temperature
  - Negative effects
    - Thermal stress in Central Europe population
    - Possible worsening in growth conditions due to climate change
- Chlorophyll
  - Negative effects
    - Eutrophication might have negative effects on bream growth
    - Water quality improvement might have positive effects on bream growth

Acknowledgments

This work has received funding from ERDF/ESF project "Biomanipulation as a tool for improving water quality of dam reservoirs" (No. CZ.02.1.01/0.0/0.0/16_025/0007417).