Combined effects of temperature and cadmium on membrane phospholipid composition, oxidative and antioxidant capacities and lipid peroxidation in two freshwater fishes

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Introduction

- Poikilotherms adapt the composition of their cell membrane phospholipid fatty acids according to temperature (modification of fatty acid unsaturation) to maintain membrane fluidity and function: **homeoviscous adaptation (HVA)**
- Metals can induce reactive oxygen species production and as a consequence, enhanced lipid peroxidation
- Membranes enriched with PUFA, typical of cold acclimation, are more prone to lipid peroxidation

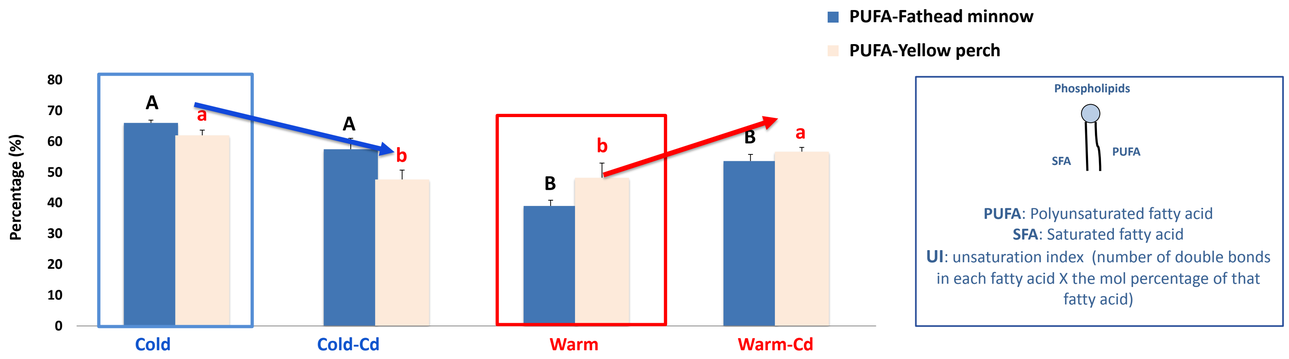
➡ We do not know whether changes in membrane composition that occur during thermal acclimation modify their vulnerability to metal-induced lipid peroxidation

Objectives

In two species of fish acclimated to different temperatures and exposed or not to cadmium:

- Compare phospholipid membrane composition and susceptibility to lipid peroxidation
- Examine the relationships between membrane composition, oxidative and antioxidant capacities
- Evaluate enzymatic indicators of oxidative capacities and antioxidant defense

Membrane fatty acid composition



*Different superscript letters of the same case (black for fathead minnow; red for yellow perch) indicate significant differences (Tukey and Wilcoxon ($p \leq 0.05$)

Cell membrane phospholipids of cold-acclimated fish were enriched in PUFA

In warm-acclimated fish, PUFA decreased

Agrees with **homeoviscous adaptation** to maintain membrane fluidity

Cd exposure

Fathead minnow: PUFA increased at 28°C
Yellow perch: PUFA decreased at 9°C and increased at 30°C

➡ Cd exposure modified the normal response to thermal stress

Methods

Experimental design

Pimephales promelas

15°C	Without metal	Cd (6µg/l)
30°C	Without metal	Cd (6µg/l)

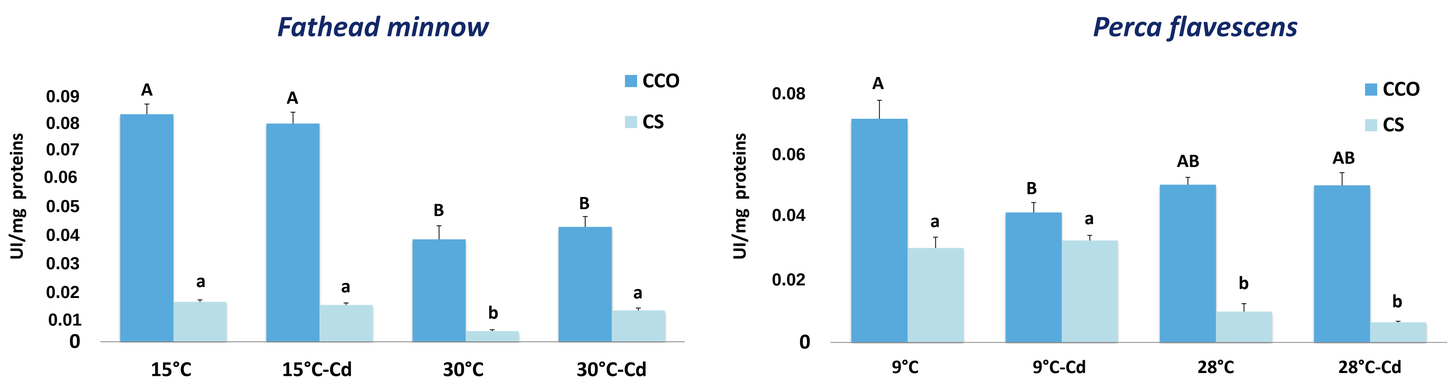
Perca flavescens

9°C	Without metal	Cd (6µg/l)
28°C	Without metal	Cd (6µg/l)

Lipid extraction and FAME analysis

Chloroform/methanol extraction
→ Polar lipids / Apolar lipids
→ Esterification (BF_3, 75°C)
→ FAME
→ Purification
→ GC-FID

Oxidative capacity



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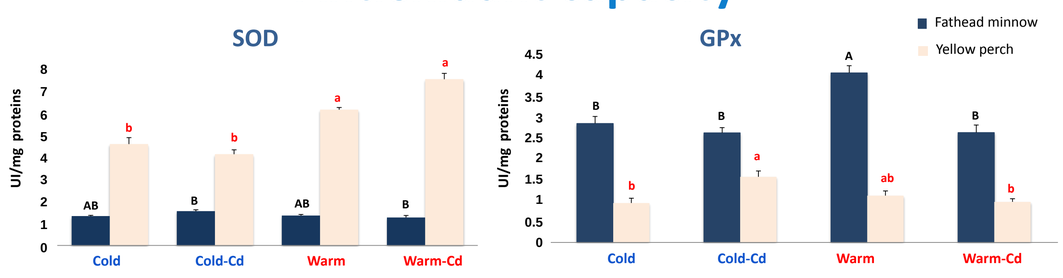
Cold acclimation: ↑ oxidative capacities

CS increase in Cd-exposed warm-acclimated fathead minnows: Cd exposure modified the normal response to thermal stress

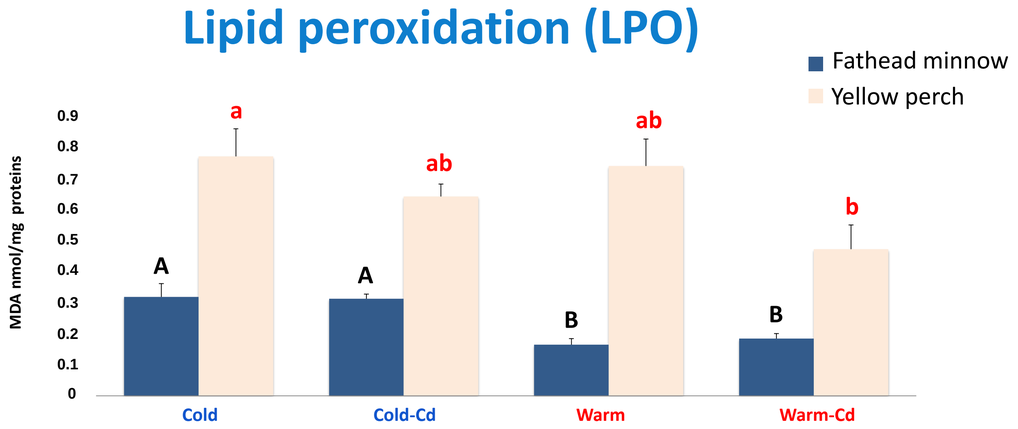
In cold-acclimated yellow perch, CCO activity was sharply decreased by Cd exposure

Antioxidant capacity



The activities of antioxidant enzymes were different under the same Cd concentration and thermal stress ➡ Interspecific response

Lipid peroxidation (LPO)



Fathead minnow

Cold acclimated fish: PUFA ↑ (More prone to lipid peroxidation) ➡ MDA increase

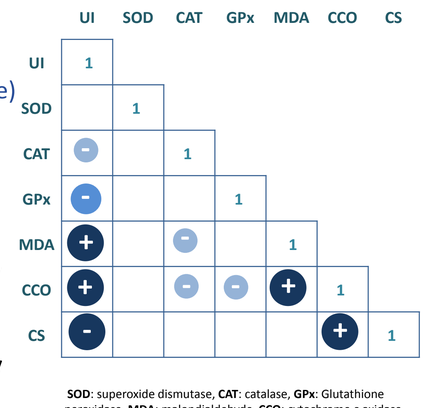
Yellow perch

In warm acclimated fish under Cd exposure: despite the high PUFA percentage, MDA was lower than in cold acclimated fish
➡ antioxidant defense efficiency?

Membrane lipid remodeling, lipid peroxidation, oxidative and antioxidant capacity

- CCO activity was positively correlated with the unsaturation index
- CCO activity correlated with 18:0 (negative) 20:5n3 (positive) and 22:6n3 (positive)
- 18:0, 20:5n3 and 22:6n3 are important components of cardiolipin

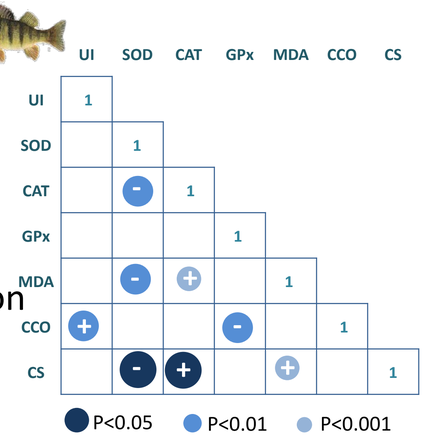
Our study suggest that changes of fatty acids in the vicinity of CCO may contribute to the increase of its activity in cold-acclimated fish



SOD: superoxide dismutase, **CAT**: catalase, **GPx**: Glutathione peroxidase, **MDA**: malondialdehyde, **CCO**: cytochrome c oxidase, **CS**: citrate synthase,

- CCO activity was also correlated with the unsaturation index

Our study suggests that Cd-induced modifications of membrane composition and affects CCO activity in cold-acclimated yellow perch



Conclusions

Combined exposure to Cd and elevated temperature modified the normal response to thermal stress
Oxidative capacities are affected by changes in temperature and Cd exposure
CCO activity is affected by membrane composition
The rate of LPO generally increased with unsaturation
In warm-acclimated perch exposed to Cd, the risk of LPO was likely countered by the action of antioxidant enzymes