Top-down and bottom-up control of plankton structure and dynamics in hypertrophic fishponds

Jaroslav Vrba,
Karel Šimek, Michal Šorf, Libor Pechar, Marek Baxa, Martin Musil,
Bořek Drozd, Lenka Kajgrová, Ján Regenda

University of South Bohemia in České Budějovice
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Brief history of Czech fishponds

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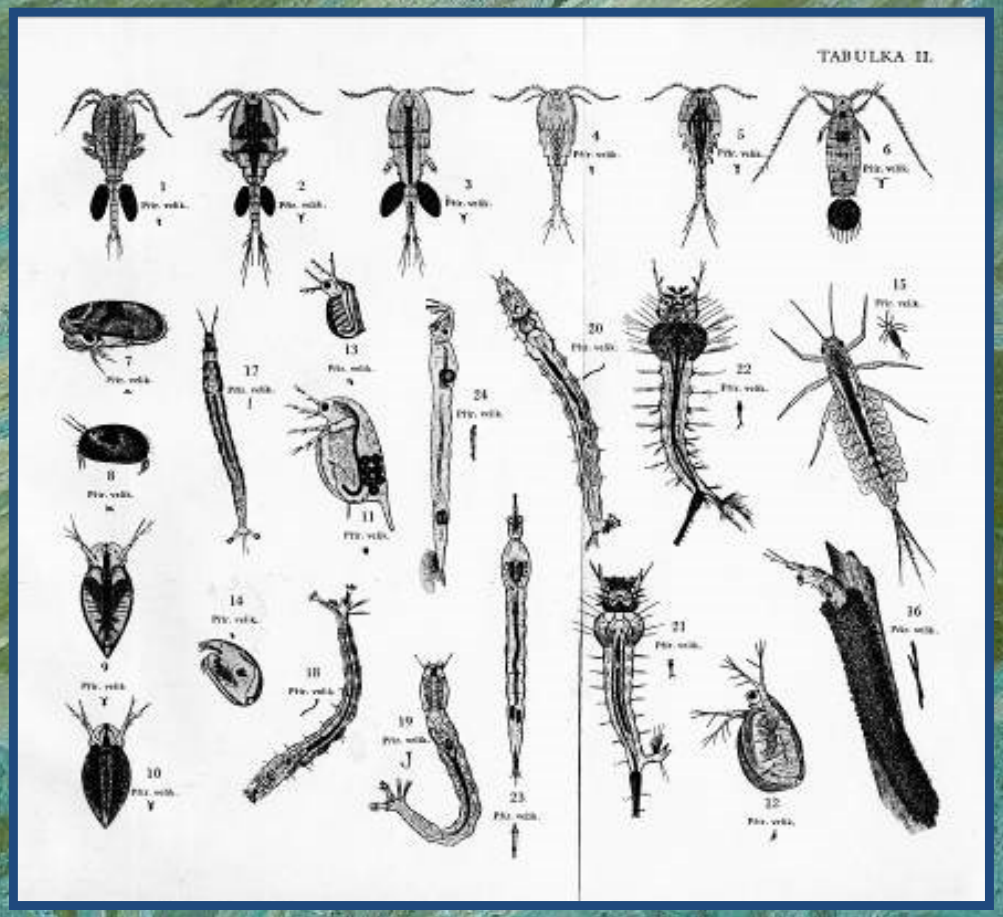
Josef Šusta – science-based aquaculture (since 1876)

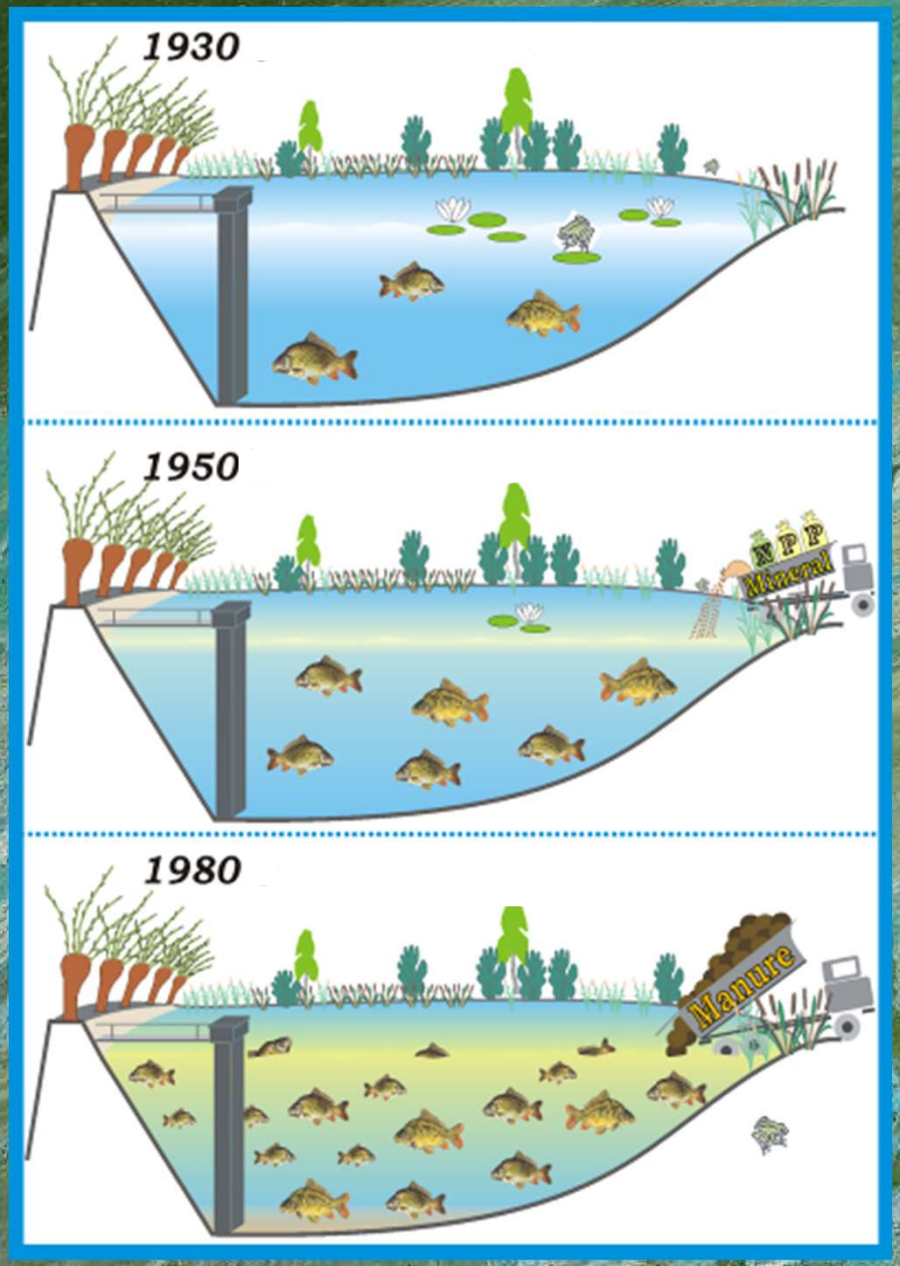
- studied **carp nutrition** and natural fish production in 20 fishponds (mesotrophic, humic, 11–94 kg/ha)

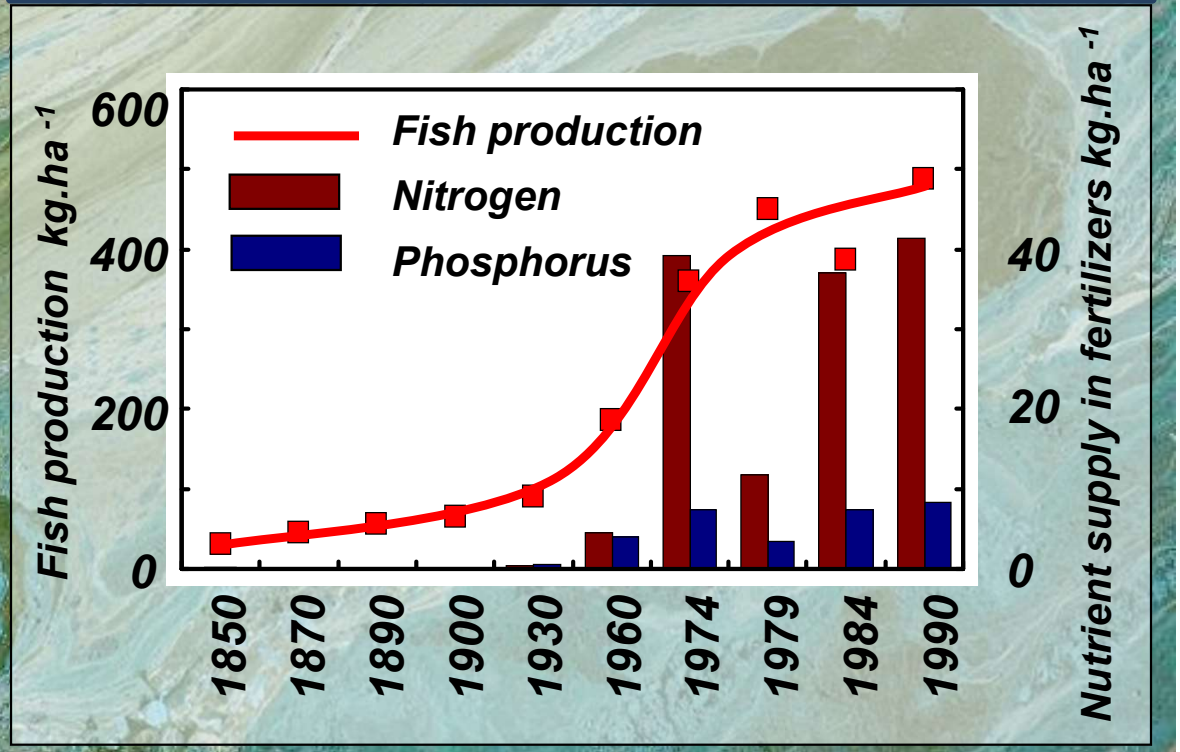


- **manuring (C_{org}, N, P) + liming (Ca) = carp production**

Brief history of Czech fishponds

A ten-fold increase in fish stock and nutrients during the last century!





Brief history of Czech fishponds

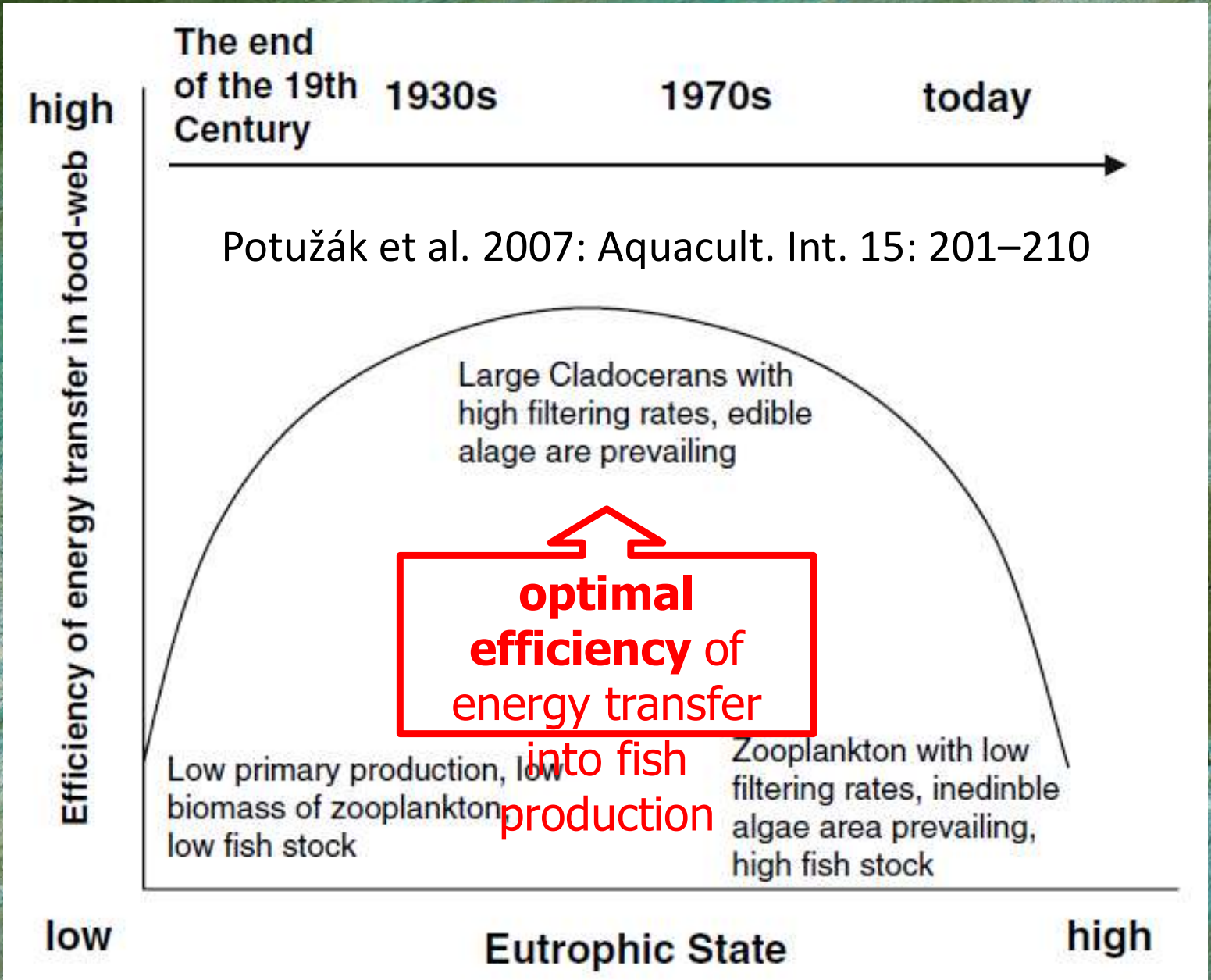
Table 2. Long-term changes in the concentrations of nitrogen and phosphorus, chlorophyll-*a*, and transparency (average values)

	Concentration (mg L^{-1})							
Period*	pH	NO_3 -N	NH_4 -N	TN	PO_4 -P	TP	Chlorophyll-*a* (µg L^{-1})	Transparency (m)
1954–1958	8.3	0.07	0.09	1.00	–	0.20	35	1.70
1973–1978	8.2	0.13	0.39	1.27	0.05	0.11	66	1.27
1979–1980	8.3	0.11	0.11	1.55	0.04	0.12	48	0.97
1990–1991	8.5	0.12	0.12	2.60	0.05	0.29	121	0.45
1992–1993	8.2	0.14	0.23	2.48	0.09	0.24	95	0.52
1994–1997	8.4	0.13	0.18	2.94	0.05	0.29	139	0.47

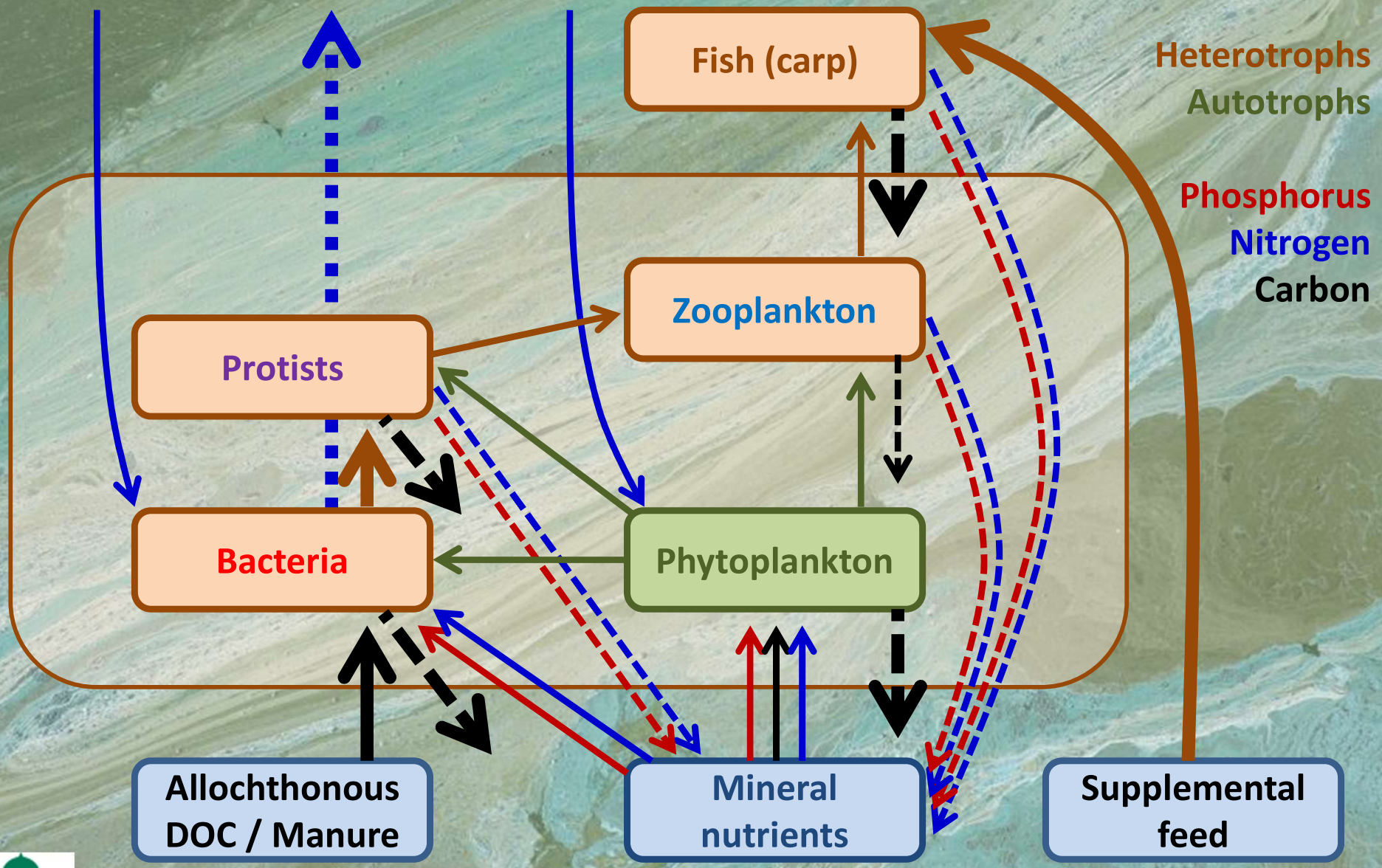
*Data source: (1954–1958) nine fish ponds in Blatná Region sampled from six to eight times a season; (1973–1978) 12 fish ponds in the Blatná and Třebon regions sampled 10–12 times a season; (1979–1980) 33 fish ponds in Blatná Region sampled three times a season; (1990–1991) 40 fish ponds in Třebon Region sampled three times a season; (1992–1993) 40 fish ponds in Třebon Region sampled three times a season, and 91 fish ponds in Třebon Region sampled five times in 1992 for transparency and chlorophyll; and (1994–1997) six fish ponds in Třebon Region sampled 14–16.

Pechar L. 2000: Fisheries Management and Ecology 7: 23–31

Brief history of Czech fishponds



Planktonic food webs in hypetrophic fishponds



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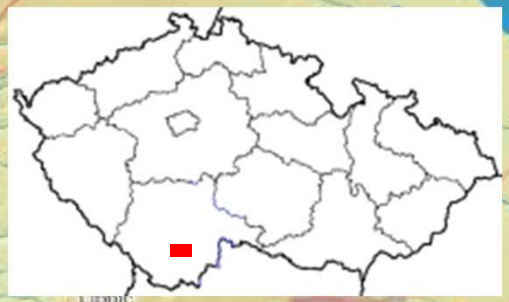
Planktonic food webs in hypetrophic fishponds

pH	NO_3-N	NH_4-N	TN	PO_4-P	TP	Chla	Transp.	DIN:DP
8.5	0.08	0.14	3.21	0.04	0.26	137	0.47	3.81

Mixed samples from 9/4 fishponds (3–6 times in 2017/2018)
(mean values in mg/L, µg/L, m, molar)

So far no change since the 1990s.



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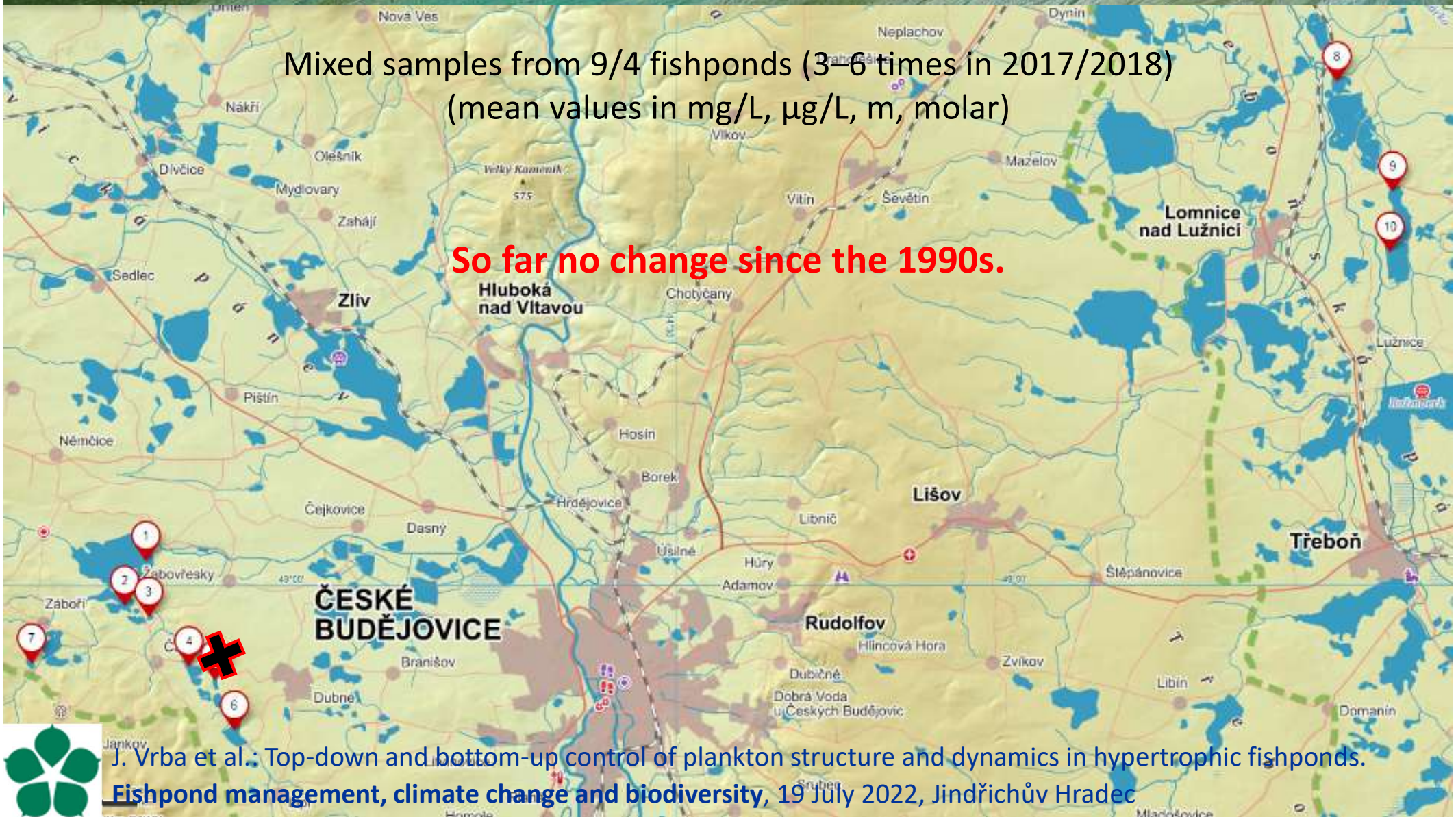

Planktonic food webs in hypetrophic fishponds

Phytopl. C	Picocyanob.	Bacteria	HNF	Ciliates	Rotifers
7.6 mg/L	0.9×10^{9} b./L	18×10^{9} b./L	9×10^{6} b./L	0.3×10^{6} b./L	7×10^{3} ind./L

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(mean values)

Microplankton forms a 'green activated sludge':

- **high abundance and diversity**
- **high biomass and productivity**
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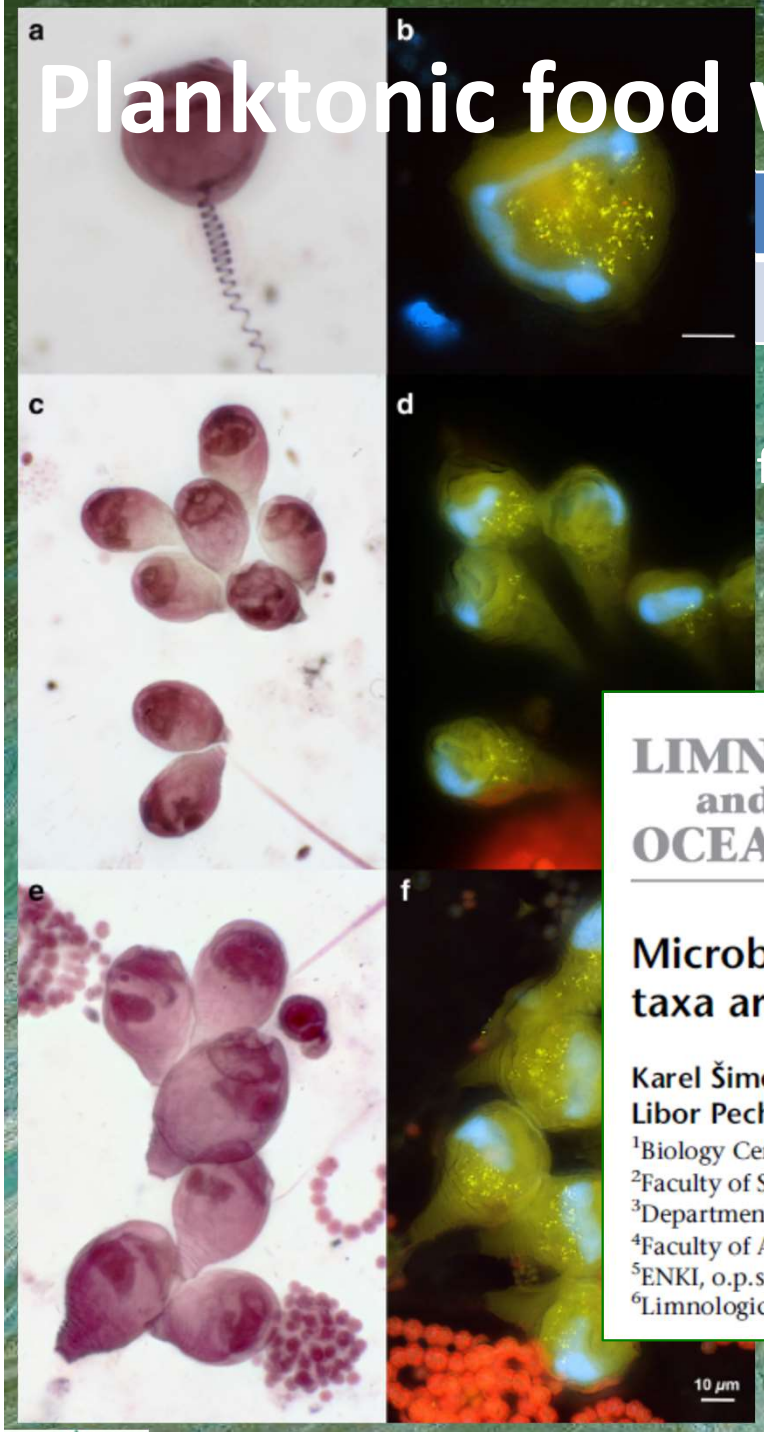
- **common oxygen depletions**

Planktonic food webs in hypetrophic fishponds



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LIMNOLOGY and OCEANOGRAPHY

ASLO

Limnol. Oceanogr. 64, 2019, 2295–2309

doi: 10.1002/lno.11260

Microbial food webs in hypertrophic fishponds: Omnivorous ciliate taxa are major protistan bacterivores

Karel Šimek,[1,2*] Vesna Grujčić,[1] Jiří Nedoma,[1] Jitka Jezberová,[1] Michal Šorf,[2,3] Anna Matoušů,[1] Libor Pechar,[4,5] Thomas Posch,[6] Estelle P. Bruni,[6,†] Jaroslav Vrba[1,2]

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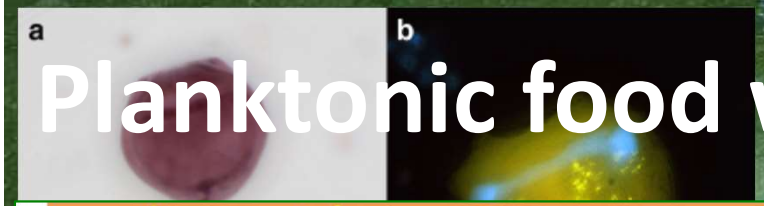
[2]Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic
[3]Department of Zoology, Fisheries, Hydrobiology and Apiculture, Mendel University in Brno, Brno, Czech Republic
[4]Faculty of Agriculture, University of South Bohemia, České Budějovice, Czech Republic
[5]ENKI, o.p.s., Třeboň, Czech Republic
[6]Limnological Station, Department of Plant and Microbial Biology, University of Zurich, Kilchberg, Switzerland

Planktonic food webs in hypetrophic fishponds



environmental microbiology

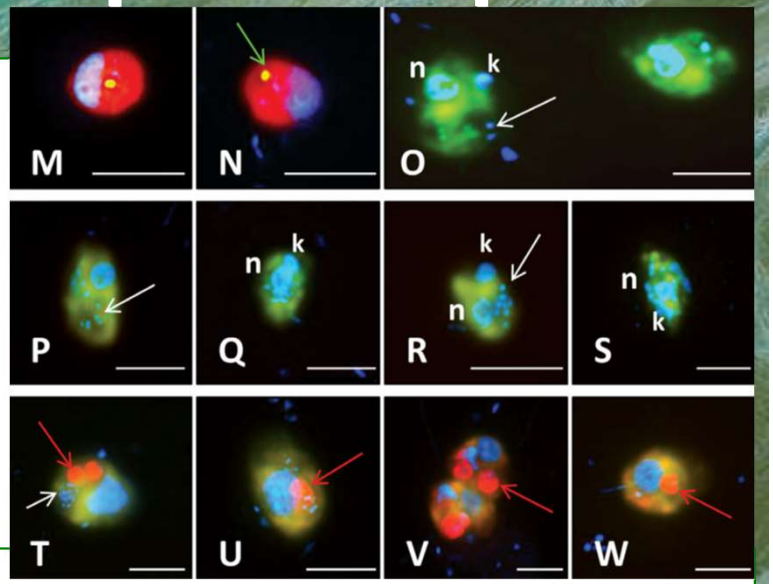
Environmental Microbiology (2021) 00(00), 00–00 doi:10.1111/1462-2920.15846

CARD-FISH and prey tracer techniques reveal the role of overlooked flagellate groups as major bacterivores in freshwater hypertrophic shallow lakes

Karel Šimek,[1,2*] Indranil Mukherjee,[1] Jiří Nedoma,[1] Caio César Pires de Paula,[1] Jitka Jezberová,[1] Dagmara Sirová[1] and Jaroslav Vrba[1,2]

[1]Biology Centre CAS, Institute of Hydrobiology, Na Sádkách 7, České Budějovice, 37005, Czech Repu

[2]Faculty of Science, University of South Bohemia, Branišovská 1760, České Budějovice, 37005, Czech Republic.



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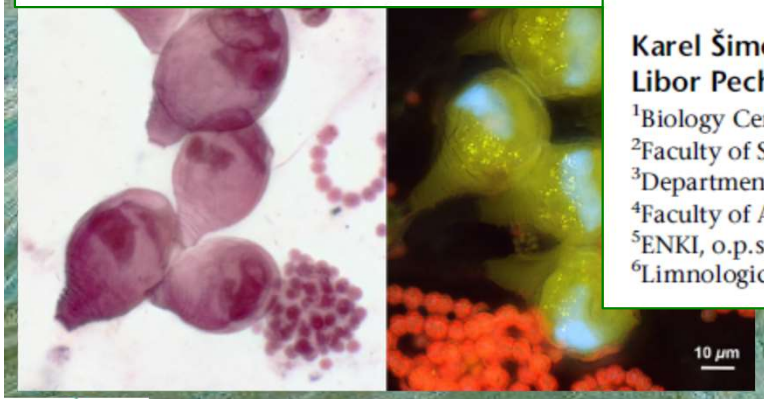

Planktonic food webs in hypetrophic fishponds

Science of the Total Environment 766 (2021) 142647

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Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Dissolved oxygen deficits in a shallow eutrophic aquatic ecosystem (fishpond) – Sediment oxygen demand and water column respiration alternately drive the oxygen regime

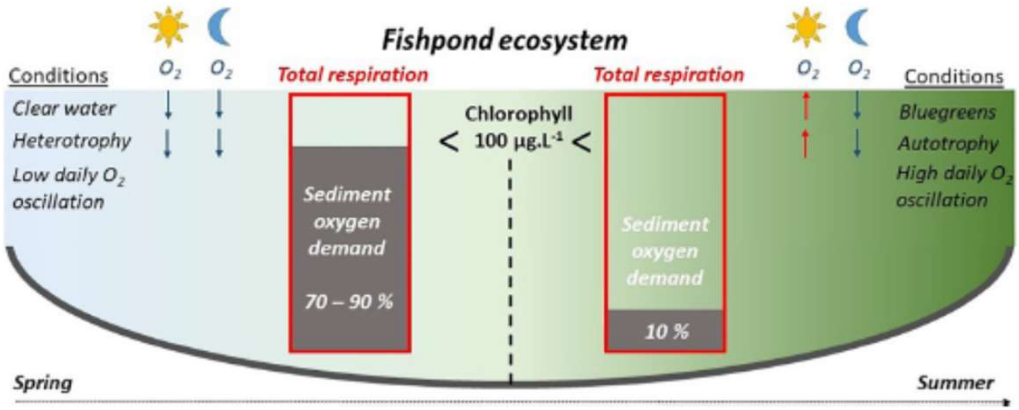
Marek Baxa [a,*], Martin Musil [a,b], Miroslav Kummel [c], Petr Hanzlík [a], Blanka Tesařová [a,b], Libor Pechar [a,b]

[a] Enki, o. p. s. – Public Benefit Corporation for Environmental Research, Education and Public Awareness, Dukelská 145, 37901, Třeboň, Czech Republic
[b] Department of Landscape Management, Faculty of Agriculture, University of South Bohemia in České Budějovice, Branišovská 1645/31a, 37005, Czech Republic
[c] Environmental Studies Program, Colorado College, 14 E. Cache La Poudre St., Colorado Springs, CO 80903, United States of America

HIGHLIGHTS

- Mesocosm experiments describe oxygen regime in an eutrophic shallow water, fishpond.
- Water column and the sediment alternate as key drivers of the oxygen regime
- Sediment plays a key role in the oxygen regime during clear water state.
- Water column plays a key role in oxygen regime during a summer phytoplankton bloom.

GRAPHICAL ABSTRACT



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Fishpond management, climate change and biodiversity, 19 July 2022, Jindřichův Hradec

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(mean values)

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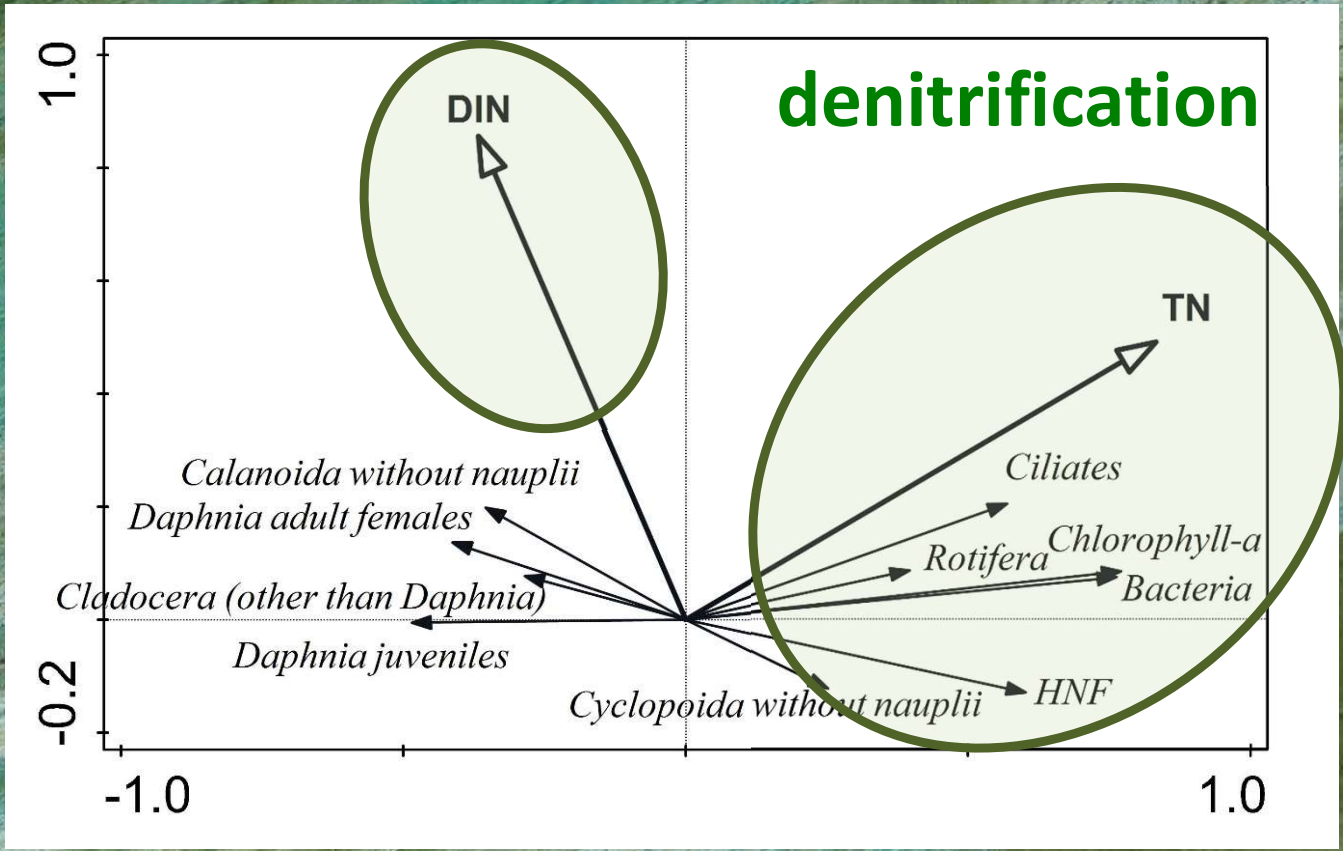
- **high biomass and productivity**
- **high activity of microbial processes**
- **high nutrient turnover**
- **common oxygen depletions**

Large crustacean zooplankton may be reduced and keystone species (*Daphnia* spp.) often absent!

Factors controlling plankton dynamics

TN + **DIN** = total and mineral **nitrogen** (**bottom-up** effect)

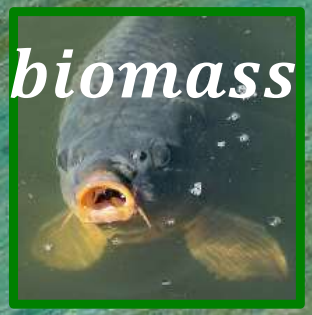


Parameter	Explains %	pseudo-F	P
TN	**22.1**	**12.5**	**0.004**
DIN	**8.9**	**5.5**	**0.004**

Factors controlling plankton dynamics

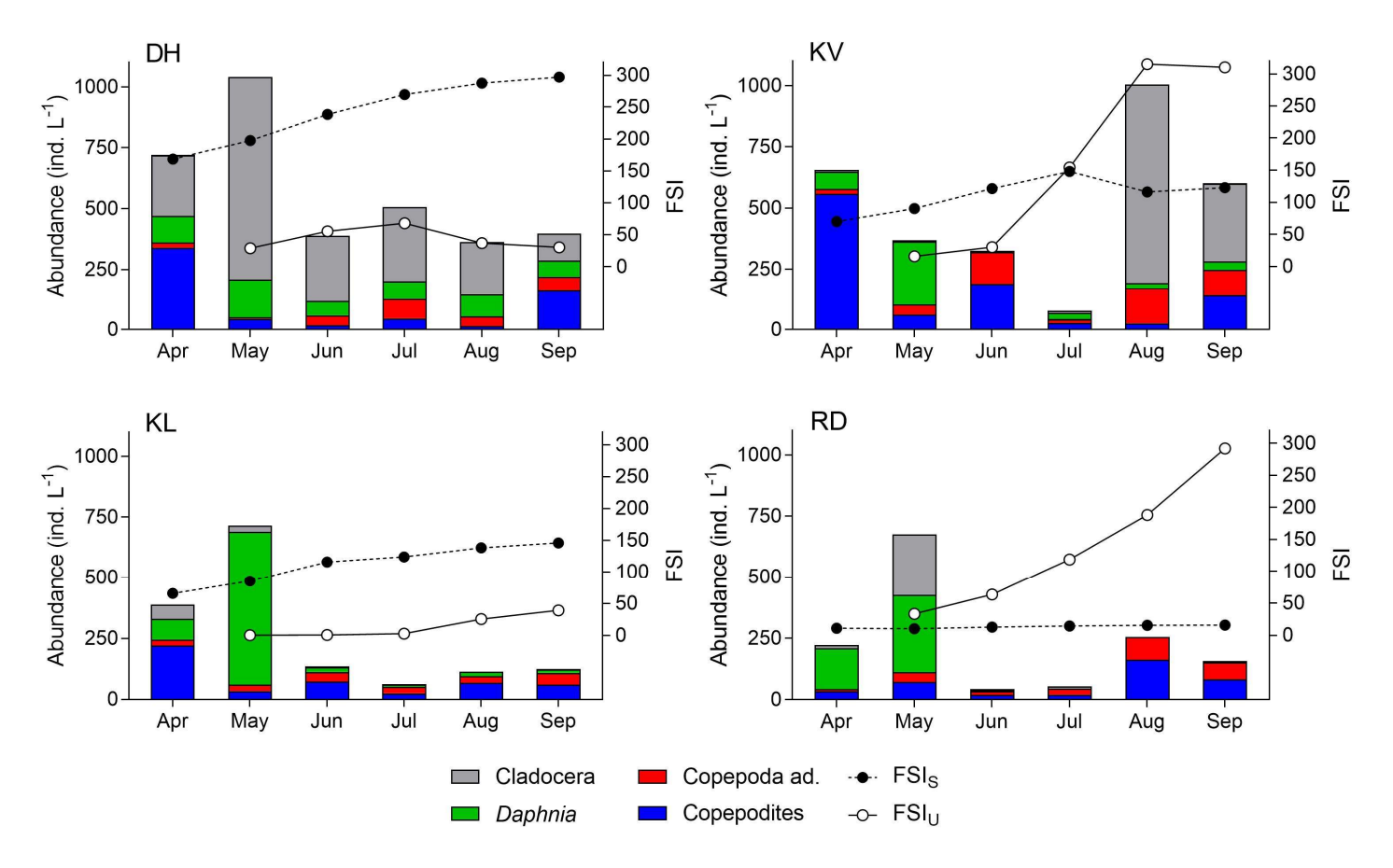
Fish Stock Index as a **proxy of fish predation**

$$\mathbf{FSI} = \boldsymbol{fish\ biomass}\ [kg/ha] \times \sqrt{\boldsymbol{fish\ density}\ [ind./ha]}$$



Factors controlling plankton dynamics

FSI_S + FSI_U = fish stock predation pressure (**top-down** effect)



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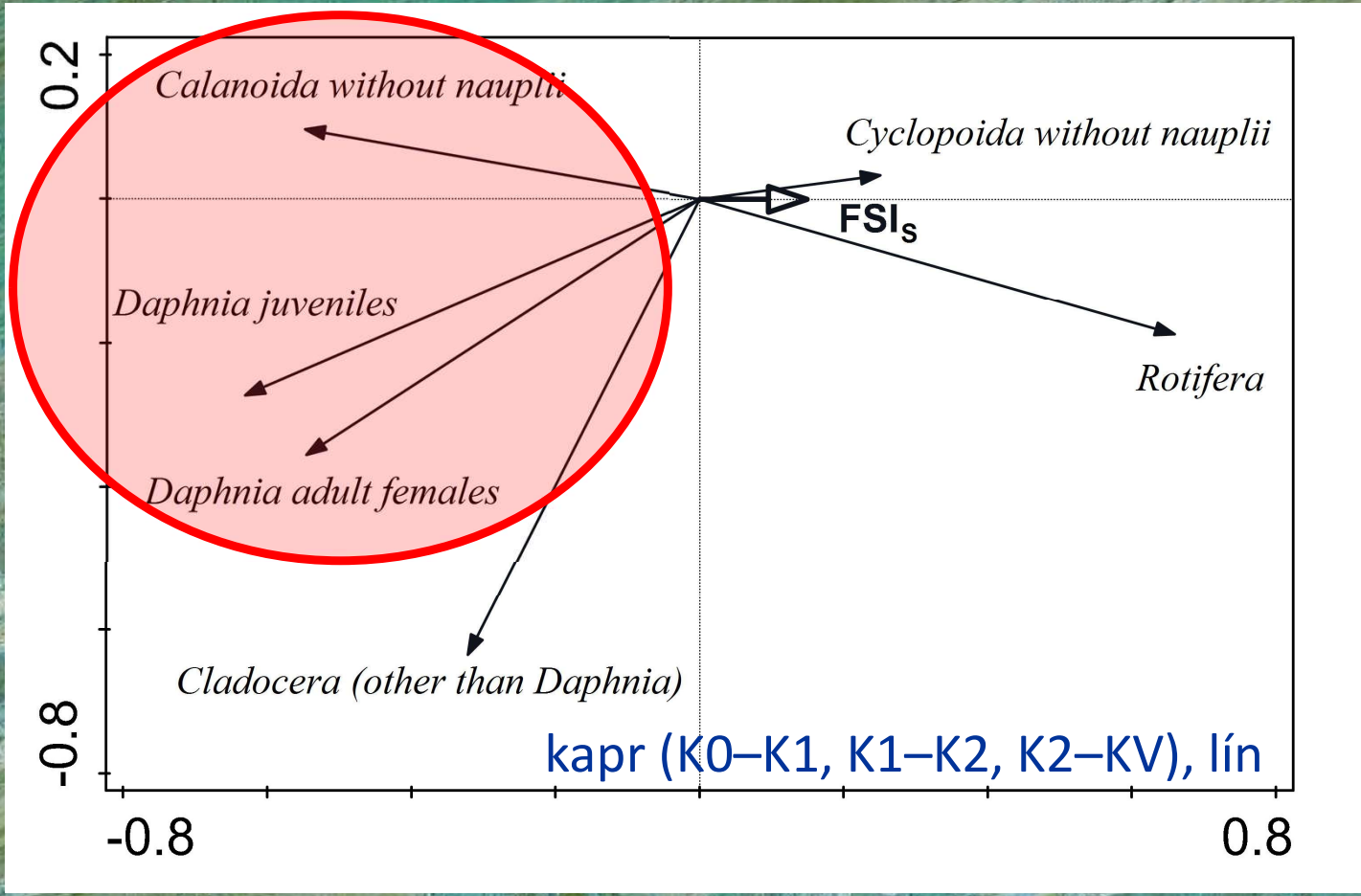

Factors controlling plankton dynamics

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Negative effects of undesirable fish on common carp production and overall structure and functioning of fishpond ecosystems

Lenka Kajgrová [a,*], Petr Blabolil [b,c], Bořek Drozd [a], Koushik Roy [a], Ján Regenda [a], Michal Šorf [c,d], Jaroslav Vrba [b,c]

[a] University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters, South Bohemian Research Center of Aquaculture and Biodiversity of Hydrocenoses, Institute of Aquaculture and Protection of Waters, Na Sádkách 1780, 370 05 České Budějovice, Czech Republic
[b] Institute of Hydrobiology, Biology Centre CAS, Na Sádkách 7, 370 05 České Budějovice, Czech Republic
[c] University of South Bohemia in České Budějovice, Faculty of Science, Branišovská 1760, 370 05 České Budějovice, Czech Republic
[d] Mendel University in Brno, Faculty of AgriSciences, Zemědělská 1, 613 00 Brno, Czech Republic

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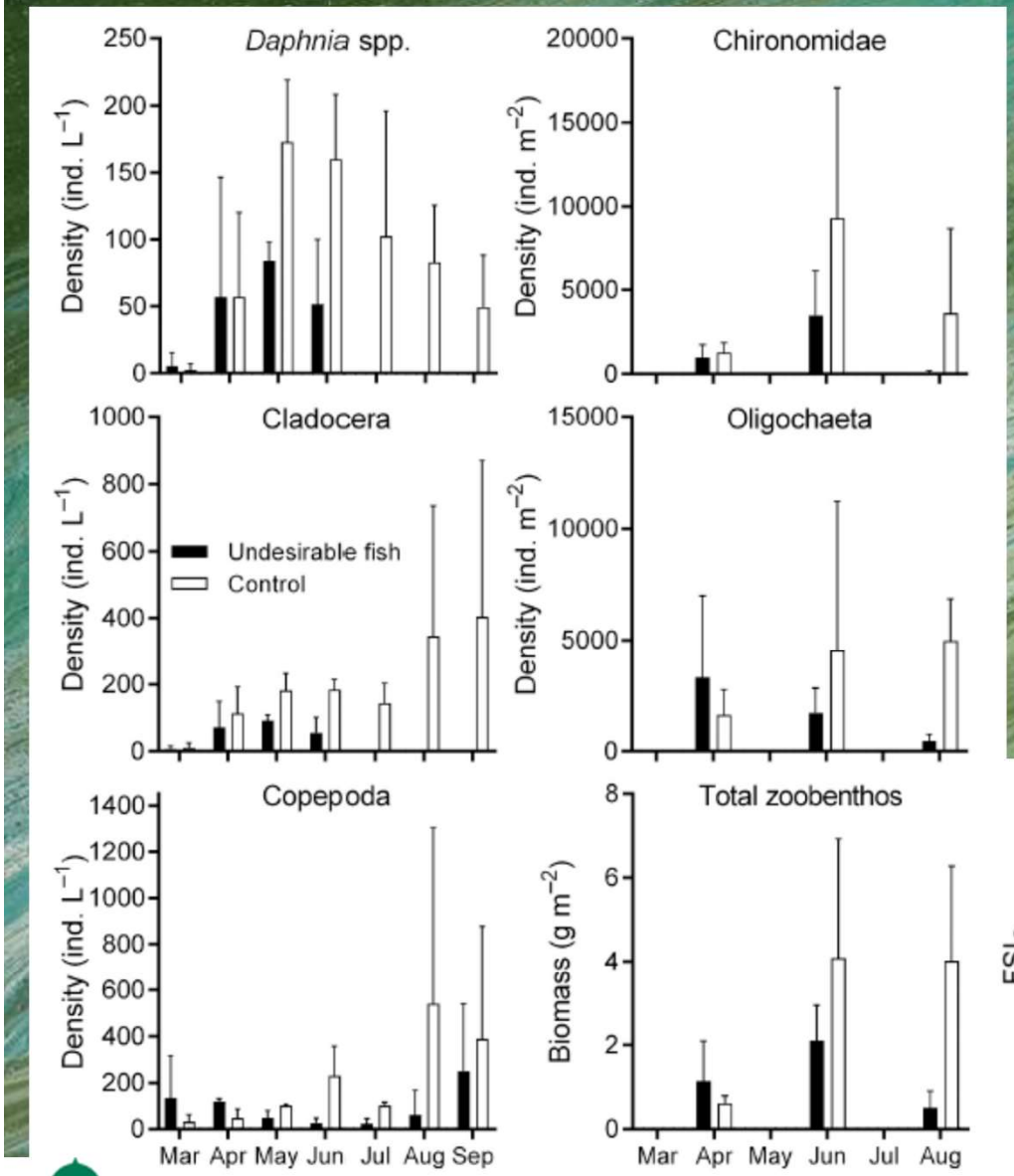

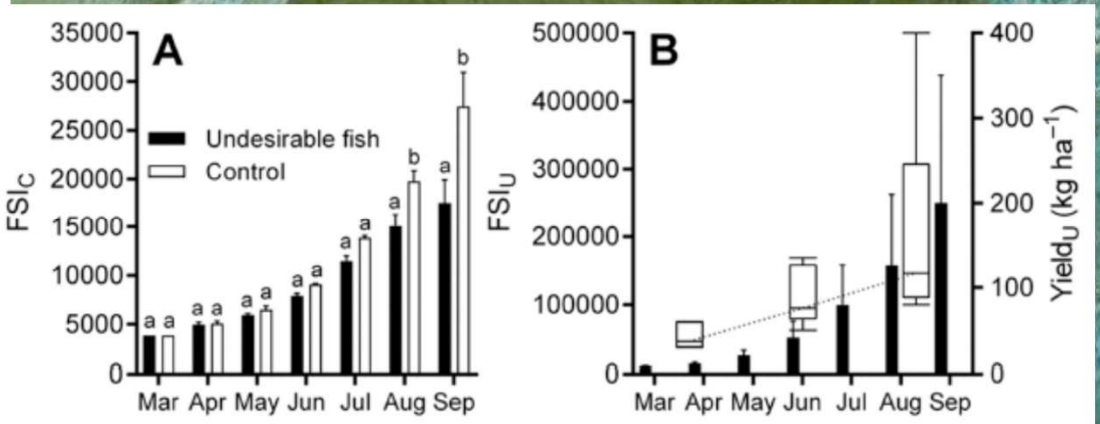

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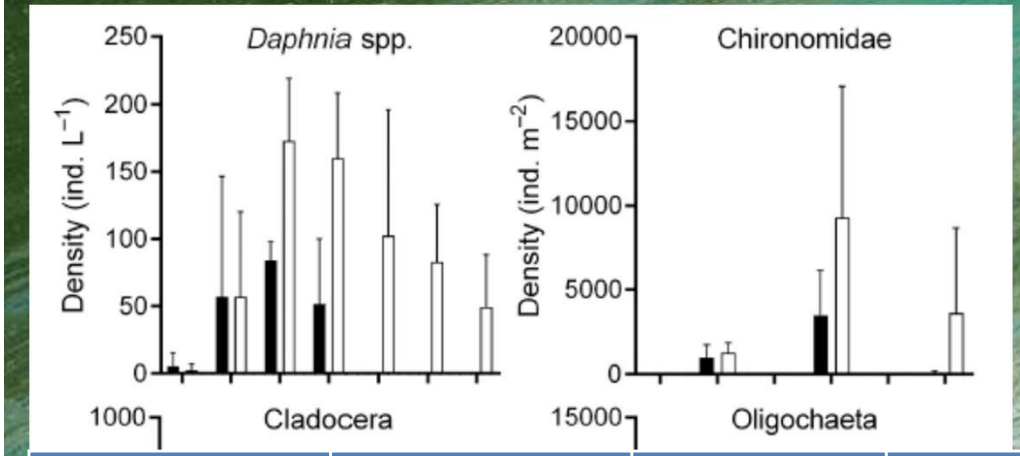
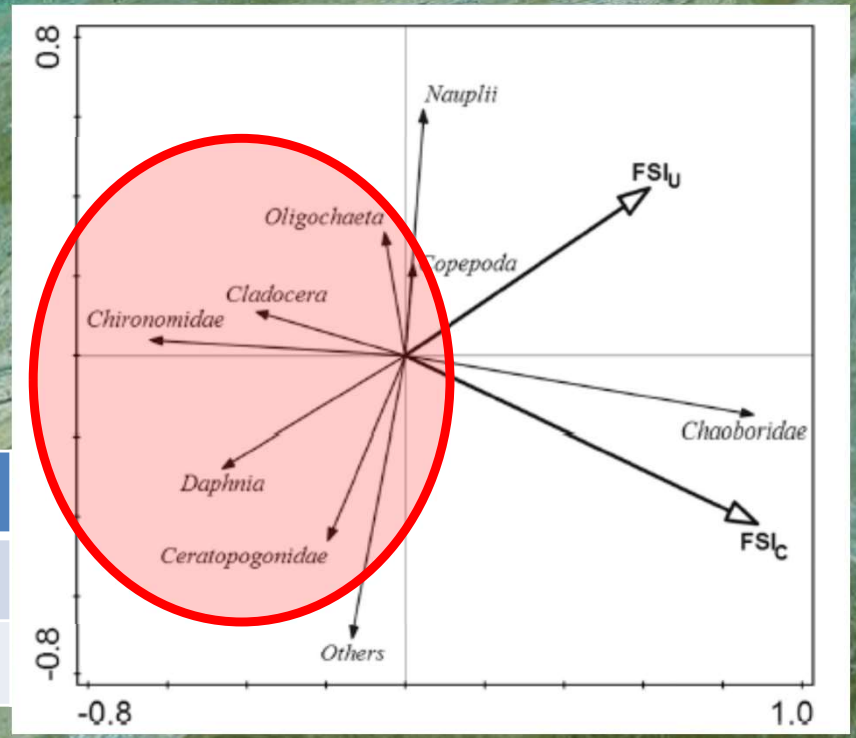
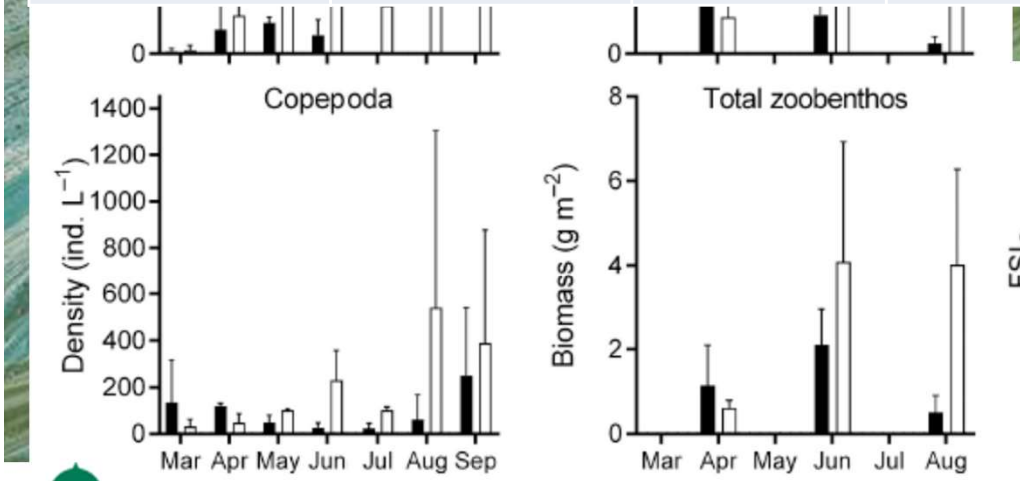
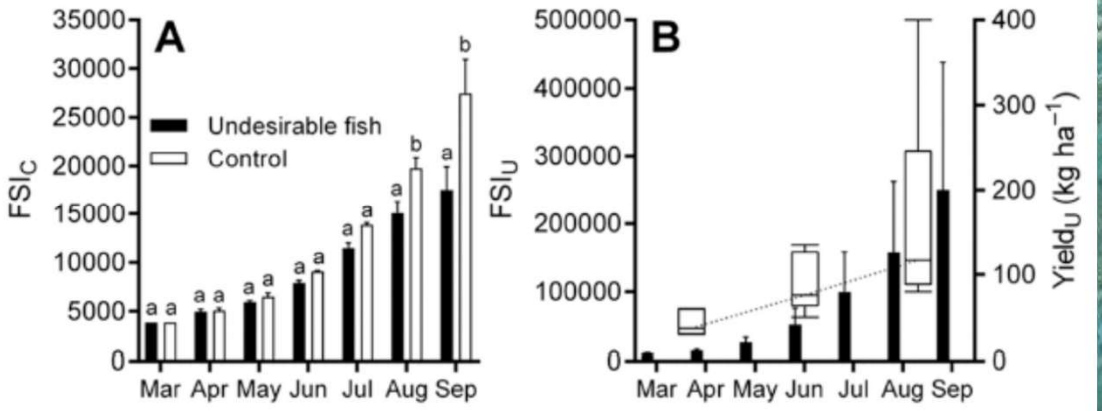


Parameter	Explains %	pseudo-F	P
FSI_C	33.9	5.6	0.0054
FSI_U	24.6	5.9	0.0054







Conclusions (yet not surprising)

- high **nutrients and organic compounds** (DOC)
- frequent **oxygen deficits** support **denitrification**
- (**phyto**)**plankton** is likely **nitrogen limited**
- **phosphorus legacy** supports **cyanobacterial blooms**

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- **fish stocks** determine **zooplankton** structure and dynamics
- **FSI** is a good **proxy of fish predation pressure**
- **undesirable** (invasive) **fishes impair natural production**
- market **carp** likely may **reduce their reproduction**

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- **manuring** largely **accelerates oxygen deficits**

Thank you for attention