Biology Centre of the Academy of Sciences
of the Czech Republic, v. v. i.
INSTITUTE OF HYDROBIOLOGY
Biologické centrum AV ČR, v. v. i.,
Hydrobiologický ústav
54th ANNUAL REPORT
For the Year 2013

Published by Biology Centre of the Academy of Sciences of the Czech Republic, v. v. i., Institute of Hydrobiology, České Budějovice (founded 1955 as Hydrobiological Laboratory, Czechoslovak Academy of Sciences, Prague)

Edited by Petr Porcal / Assistant Editor by Dagmar Sirová (language revision) / Graphic design by pintos.cz / Printed in Czech Republic by Typodesign, České Budějovice

Institute of Hydrobiology, 2014
52 pages
ISSN 1210 – 9649

BIOLOGY CENTRE ASCR

Institute of Hydrobiology

BIOLOGY CENTRE OF THE ACADEMY OF SCIENCES
OF THE CZECH REPUBLIC, v. v. i., INSTITUTE OF HYDROBIOLOGY
BIOLOGICKÉ CENTRUM AV ČR, v. v. i., HYDROBIOLOGICKÝ ÚSTAV
ČESKÉ BUDĚJOVICE

54th ANNUAL REPORT

For the Year 2013

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Content / Obsah

Director's preface

Dear reader,

In your hands is the fifty-fourth edition of the annual report of the Institute of Hydrobiology, Academy of Sciences of the Czech Republic. We have always pioneered continuous basic limnological research in inland waters, reservoirs, and lakes and continue to do so. Our years of experience, combined with state-of-the-art research approaches, often leads us to unique perspectives of aquatic systems. The Institute is instrumental in maintaining continuous monitoring of major research model systems: the Římov and Slapy reservoirs, and the Bohemian Forest Lakes. Decades of information are available from these sites, some of which are integrated into the Long Term Ecological Research (LTER) and Global Terrestrial Observing System (GTOS). Along with these basic research activities, the work conducted at the Institute reflects the new challenges arising from the development in theoretical science, fulfilling societal needs and guiding water management activities.

In addition to our ongoing basic research plans, the main activities at the Institute were focused on preparing a methodology for assessing the ecological potential of heavily modified and artificial water bodies – category "lake". In the Czech Republic, there are no lakes over 50 hectares of natural origin left, so the "lake" category includes reservoirs, large ponds, and post-mining lakes. This activity was motivated by the Framework Directive of the European Parliament and Council Directive 2000/60/EC of 23 October 2000 establishing a framework for community action in the field of water policy. Water managers and hydrobiologists throughout

Lake Nižné Wahlenbergovo, Tatra mountains, Slovakia. / Nižné Wahlenbergovo pleso v Tatrách. Foto J. Kopáček.

Úvod ředitele ústavu

Vážení čtenáři a příznivci vodních věd,

Dostáváte do rukou padesátý čtvrtý ročník výroční zprávy Hydrobiologického pracoviště Akademie věd ČR. Po tuto dlouhou dobu udržujeme kontinuální výzkum základních limnologických procesů, které probíhají ve velkých stojatých vodách, nádržích a jezerech. Zúročení dlouholetých zkušeností a poznatků a zároveň aplikace nejnovějších přístupů studia v našem poracovišti vede často k unikátním pohledům na děje ve vodních systémech. Ústav pečlivě udržuje kontinuitu informací o našich hlavních modelových výzkumných objektech – nádržích Římov a Slapy a Šumavských jezerech. Na těchto lokalitách, z nichž některé jsou začleněny do mezinárodních sítí LTER (Long Term Ecological Research) a GTOS (Global Terrestrial Observing Networks), jsou k dispozici desítky let pozorování. Zároveň práce ústavu reflektuje nové výzvy vycházející z rozvoje teoretické vědy i potřeb společnosti a vodního hospodářství.

Vedle neustálého rozvíjení základního výzkumu vod byla v roce 2013 hlavní aktivitou ústavu příprava Metodiky pro hodnocení ekologického potenciálu silně ovlivněných a umělých vodních útvarů – kategorie jezero. Tato aktivita souvisí s naplňováním Rámcové Směrnice Evropského parlamentu a Rady 2000/60/ES ze dne 23. října 2000 ustavující rámec pro činnost Společenství v oblasti vodní politiky. Vodohospodářům a hydrobiologům v celé Evropě je dobře známo, jak nesnadné je definovat ekologický stav přirozených vod, hlavně toků a jezer, kde se lze opřít o člověkem málo ovlivněné referenční stavy. Ani jeden velký stojatý vodní útvar v České republice dnes nemá přirozený charakter a původ. Naše vodní útvary „kategorie jezero" jsou buďto údolní nádrže vyvořené silnou modifikací vodního toku nebo jezera zcela umělá (vesměs po důlní těžbě). Jaký má být dobrý ekologický stav (zde nazýván dle terminologie rámcové směrnice „ekologický potenciál") těchto vod, u nichž nenajdeme přirozené protějšky?

Tento problém mobilizoval prostřednictvím projektu Státního fondu životního prostředí č. 5611212 „Metodika hodnocení ekologického potenciálu silně ovlivněných a umělých útvarů stojatých vod" odborníky napříč celým ústavem. Šlo o to zhodnotit stav vodních útvarů z hlediska fyzikálně chemických ukazatelů a biologických složek: společenstev fytoplanktonu, makrofyt a ryb. Bylo nezbytné integrovat informace různorodé kvality o zhruba sedmi desítkách českých stojatých vod, vyhodnotit průkazné trendy v obrovských databázích a zamyslit se nad žádoucími a dalšími mezními hodnotami nejprůkaznějších metrik. To vše během necelého jednoho roku, během kterého bylo nutno vypustit nultou verzi Metodiky hodnocení do rukou správců nádrží a dalších zájmových skupin. Díky mimořádnému nasazení řady kolegů má dnes ČR funkční „Metodiku pro hodnocení ekologického potenciálu silně ovlivněných a umělých vodních útvarů – kategorie jezero" (Borovec a kol., 2013, Blabolil a kol., 2013), která je respektována v tuzemsku i v zahraničí. Vytvoření základní filozofie ekologického fungování vodních útvarů je výzvou i pro budoucnost. Příprava současné metodiky ukázala jasně též mnohá bílá

Europe are well aware of the difficulty to define the ecological status of natural waters, such as lakes and streams, whose near-pristine "reference states" are known. Our water bodies in the "lake" category are either reservoirs created by strong modification of existing watercourses or post-mining lakes. What should be considered a good ecological status ("ecological potential" in the terminology of the Framework Directive) for waters which do not have natural counterparts?

This particular problem was the centerpiece of the State Environmental Fund No. 561121 "Method of assessment of ecological potential for heavily modified and artificial bodies of stagnant water", which mobilized experts across the Institute. The main goal of this project was to assess the status of water bodies in terms of their physico-chemical parameters and biological components: communities of phytoplankton, macrophytes, and fish. It was necessary to integrate information about the ecological integrity of the seventy largest Czech waterbodies, to evaluate conclusive trends in different indicators computed from the databases and to investigate the desirable limits of the many proposed metrics. All these activities were conducted in less than a year in order to submit the draft version of the Evaluation Methodology to water managers and stakeholders in time for proper review. Thanks to the substantial efforts of many colleagues, the Czech Republic now has a fully functional "Methodology for assessing ecological potential for heavily modified and artificial water bodies – Category lake" (Borovec et al. 2013, Blabolil et al. 2013). This methodology has undergone substantial peer review and has achieved both national and international recognition. Creating basic philosophy of ecological functioning of water bodies is a challenge for the future. The preparation of the current methodology clearly showed where our knowledge is missing. Achieving the full ecological potential of our stagnant waters should be the impetus for uncovering the remaining secrets, for further improvement of monitoring systems and for increasing ecological research at our Institute.

As we look back on the year 2013, we can say that it was a relatively quiet year filled with tough work. Our financial situation remains challenging as only about 38% of our budget came from institutional support, which means that the vast majority of our research work required external funding from projects and contracts. We had a number of funded proposals which allowed us to secure project funds and my conclusion is that we had a positive year in 2013.

While we had a number of positive outcomes this year, we were also struck by a sad event at the end of the year. We were deeply saddened by the early passing of one of our most promising scientists, Dr. Jan Jezbera, who succumbed to a serious illness. As biologists, we understand that death is part of life, but we sorely miss Honza Jezbera's energy, erudition and humor. Despite this sad news, life in lakes and at the Institute goes on. It is sometimes through hard work that we cope with such a loss, and we thus continue our research activities.

On the following pages you will find an abbreviated digest of our most important activities, results and publications for 2013. I wish you an interesting read and hope that you will find time to enjoy our beautiful lakes and reservoirs in 2014.

Jan Kubečka

místa našich znalostí. Péče o dobrý ekologický potenciál našich stojatých vod by měla být impulzem pro odkrývání tajemství těchto bílých míst, pro rapidní zlepšování používaných monitorovacích systémů a samozřejmě i pro prohlubování ekologického výzkumu v našem ústavu.

Nyní po skončení roku 2013 můžeme konstatovat, že to byl relativně klidný rok naplněný houževnatou prací. Finanční situace pracoviště nebyla snadná, institucionální podpora pracoviště představovala jen cca 38% našeho rozpočtu, pro podporu drtivé většiny výzkumných prací tak bylo nutno získat prostředky z projektů a zakázek naší hlavní činnosti. To se očividně v mnoha případech podařilo a tak bych mohl uzavřít, že byl rok 2013 rokem příznivým.

Dobrý dojem kalí smutná událost, která nás postihla koncem roku. Je to předčasná smrt jednoho z nejnadějnějších mladých pracovníků ústavu, RNDr. Jana Jezbery, Ph.D. Opustil nás v rozpuku svých sil po nedlouhé těžké nemoci. My biologové víme, že smrt patří k životu, avšak síly, erudici a humor Honzy Jezbery budeme ještě dlouho postrádat. Život v jezerech i v ústavech však jde dál a i nám nezbylo než se se ztrátou vyrovnat a pokračovat v práci. Na dalších stránkách najdete zkrácený výtah nejdůležitějších výsledků získaných nebo publikovaných v roce 2013.

Přeji Vám poučné čtení
a zajímavé chvíle
u nádrží a jezer.

Jan Kubečka

Beach-seining at Římov Reservoir, Czech Republic. / Odlov ryb zátahovou sítí na nádrži Římov. / Foto S. Miranda.

Deparments

Department of Hydrochemistry and Ecosystem Modelling

At the Department of Hydrochemistry and Ecosystem Modelling we investigate biogeochemical nutrient cycles and the processes that influence the chemical composition and quality of surface waters. We focus especially on processes in lentic waters – mountain lakes, reservoirs, and ponds, but we also pay considerable attention to the hydrology of water outflowing from different types of catchments as well as to selected soil-bound processes that influence the transport of mineral and organic matter into surface waters. One part of our research is linked to long-term monitoring of model reservoirs, especially the Slapy and Římov reservoirs in the catchment of the Vltava river; another important area of study involves apline lakes in the Tatra mountains and mountain lakes in the Bohemian Forest (Šumava). For a more detailed understanding of key processes we complement our monitoring activitites with field and laboratory experiments and with the application of mathematical models. Two crucial areas of our research concern eutrophication and acidifaction of aquatic ecosystems.

Pohořský stream. / Pohořský potok. Foto P. Porcal.

Eutrophication is the enrichment of ecosystems by nutrients, leading to intensive growth of biomass of algae, cyanobacteria

Oddělení

Oddělení hydrochemie a ekosystémového modelování

V oddělení hydrochemie a ekosystémového modelování zkoumáme biogeochemické koloběhy živin a procesy, které ovlivňují chemické složení a kvalitu povrchových vod. Zaměřujeme se především na procesy ve stojatých vodách – horských jezerech, údolních nádržích a rybnících, ale velkou pozornost věnujeme také hydrologii odtoku vody z různých typů povodí a vybraným procesům v půdním prostředí, které ovlivňují odnos minerálních a organických látek do povrchových vod. Jedna část našich studií je založena na dlouhodobém monitoringu modelových nádrží, zejména nádrží Slapy a Římov v povodí Vltavy, druhou oblastí je výzkum alpinských jezer v Tatrách a lesních horských jezer na Šumavě. Pro detailní studium klíčových procesů monitoring doplňujeme terénními a laboratorními experimenty a rovněž aplikací matematických modelů. Dvěma stěžejními tématy bádání jsou eutrofizace a acidifikace vodních ekosystémů.

Eutrofizace je obohacování ekosystému živinami, jejímž důsledkem je ve stojatých vodách intenzivní tvorba organické hmoty řas, sinic a vodních rostlin, často doprovázená nežádoucím výskytem vodního květu, anoxiemi vody nade dnem, zhoršenou jakostí vody atd. Náš výzkum eutrofizace pokrývá všechny podstatné aspekty této problematiky od určování a řízení zdrojů živinového znečištění v povodí, přes transport živin říční sítí do nádrží, až po podmínky pro realizaci živin při tvorbě biomasy ve vlastní nádrži. Pro hodnocení významnosti různých přírodních

Exposure of water samples to natural solar radiation. / Vystavení vzorků vody slunečnímu záření. Foto P. Porcal.

Meteorology station — bulk precipitation measurement. / Meteorologická stanice – měření srážek. Foto P. Porcal.

and aquatic plants, often accompanied by unwelcome incidence of water blooms, anoxia of water above the bottom, decrease in water quality, etc. Our eutrophication research topics cover all the important aspects of this issue: from the determination and management of sources of nutrient pollution in the catchment area, research on the transport of nutrients via the river network into the reservoirs, and to investigations of the conditions necessary for nutrients to actually trigger the creation of biomass in the reservoir. To evaluate the importance of various natural and anthropogenic sources of nitrogen and phosphorus in individual catchments we use mathematical models of varying complexity, from simple empirical mass-balance equations all the way to dynamic complex models based on detailed descriptions of hydrological, physico-chemical, and biochemical processes in the soil, in groundwater, and in the river network. We evolve and develop methods to determine different nutrient forms and their accessibility within the catchment area and during their intra-reservoir circulation between the sediments and the water column. A more recent addition to our research in this area has been the influence of environmental conditions and of reservoir management on aquatic macrophytes.

In our research on the recovery from **acidification** of mountain lake ecosystems and their catchment areas in Central Europe we exploit the unique opportunity to understanding the reactions in different sections of the terrestric and aquatic ecosystems of catchments and lakes to pollution, that was at one time extreme, but that has returned to levels from the first half of the 20th century in the last two decades. While the level of atmospheric pollution by sulphur and nitrogen entering the catchments is currently very low, acidification levels in the soil and waters remain relatively high and ecosystem recovery is slow. Forest dieback in the catchment area due to bark beetle infestation enables us to investigate the dynamics of interactions between plants and microbial communities in the soil. It also gives

a antropogenních zdrojů dusíku a fosforu v konkrétních povodích používáme matematické modely o různé složitosti, od jednoduchých empirických bilančních rovnic až po dynamické komplexní modely pracu-

Calibrated weir for flow measurement near Čertovo Lake. / Kalibrovaný přeliv pro měření průtoku poblíž Čertova jezera, Foto J. Turek.

jící s detailním popisem hydrologických, fyzikálně-chemických a biochemických procesů v půdě, podzemní vodě a v říční síti. Vyvíjíme a dále rozpracováváme metody pro stanovení různých forem živin a jejich dostupnosti v povodí i ve vnitronádržovém koloběhu mezi sedimenty a vodním sloupcem. V poslední době byla výzkumná problematika oddělení doplněna o studium vlivu environmentálních podmínek a nádržového managementu na vodní makrofyta.

Při studiu zotavování ekosystémů horských jezer a jejich povodí ve střední Evropě z **acidifikace** neboli okyselení, využíváme unikátní příležitost k porozumění procesům v různých složkách terestrické-

ho a vodního ekosystému povodí a jezer při jejich reakci na extrémní znečištění, které se v dvou posledních desetiletích opět vrátilo na úroveň z první poloviny 20. století. I když atmosférické znečištění sloučeninami síry a dusíku vstupující do povodí je v současnosti velmi nízké, v půdním i vodním prostředí okyselení dosud přetrvává a zotavování ekosystémů probíhá jen postupně. Odumírání lesních porostů v povodí v důsledku kůrovcové kalamity poskytuje možnost sledovat

us the chance to study the effects of disturbed equilibria within the soil environment on the export of nutrients and organic compounds into surface outflows and their ensuing impacts on lake ecosystems. Acidified mountain catchments are also useful as model localities for research on the causes and effects of the long-term rise in the concentration of humic substances in the outflow from catchments. This phenomenon is observed in many temperate parts of the world and impacts both lake ecology and drinking water quality.

Sediment samples. / Vzorky sedimentů. Foto J. Borovec.

Department of Aquatic Microbial Ecology

The research at the Department of Aquatic Microbial Ecology is focused on freshwater microscopic organisms. There are two main groups of aquatic microorganisms, the object of our interest, and they differ by function. The first group, the autotrophs, consist of microscopic algae and cyanobacteria which are jointly referred to as phytoplankton. They are responsible for creating new organic matter via photosythesis. The second group, the heterotrophs, are the bacteria and the protozoa which, on the contrary, co-operate on the decomposition of organic matter. Because the methodology is different for each group of organisms, our department has two interlinked working groups, concerned with (1) the ecology of aquatic bacteria and protozoa (2) the ecology of phytoplankton.

The group focusing on the **ecology of aquatic bacteria is interested in** the

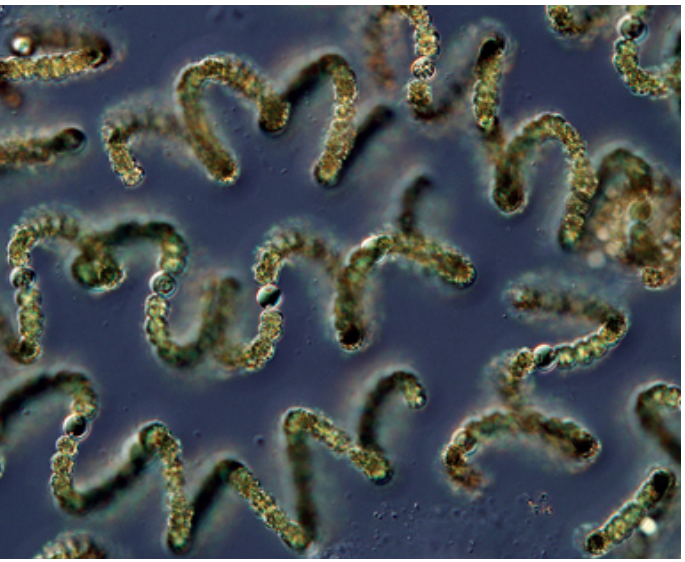
dynamiku interakcí mezi rostlinami a mikrobiálními společenstvy v půdě a důsledky narušení jejich rovnováh pro odnos živin a organických látek do povrchového odtoku a následně zkoumat dopady na vodní ekosystém jezer. Okyselením postižená horská povodí také využíváme jako modelové lokality pro výzkum příčin a důsledků dlouhodobého nárůstu koncentrací huminových látek v odtoku z povodí, ke kterému dochází v mnoha částech světa v mírném klimatickém pásmu a jenž má dopady i na ekologii jezer a jakost vodních zdrojů.

A unique culture collection of algae and cyanobacteria at IHB. / Unikátní sbírka izolovaných mikroorganismů, zejména řas a sinic, na pracovišti HBÚ. Foto P. Znachor

Oddělení mikrobiální ekologie vody

V oddělení mikrobiální ekologie vody se zabýváme výzkumem mikroskopických organismů, které žijí ve sladkých vodách. Předmět našeho zájmu, vodní mikroorganismy, se podle funkce dělí na dvě skupiny, z nichž první (autotrofové) je tvořena mikroskopickými řasami a sinicemi (souhrnně nazývanými fytoplankton) a je zodpovědná za tvorbu nové organické hmoty fotosyntézou. Druhou skupinu tvoří heterotrofové – jsou to bakterie a prvoci, kteří naopak spolupracují na rozkladu odumřelé organické hmoty. Protože se metodické přístupy ke studiu obou skupin liší, fungují z praktických důvodů v našem oddělení dvě úzce provázané pracovní skupiny, zaměřené (1) na studium ekologie vodních bakterií a prvoků, a (2) na studium ekologie fytoplanktonu.

Skupina **ekologie vodních baktérií** se zabývá **taxonomií** sladkovodních bakterií, jejich **biogeografií, funkcí**, a jejich **zapojením do potravních řetězců**. V taxonomie



Filamentous cyanobacterium Dolichospermum crassum. / Vláknitá sinice Dolichospermum crassu.m. Foto P. Znachor.

taxonomy of freshwater bacteria, their **biogeography, function,** and their **role in food chains**. In aquatic bacterial taxonomy, we try to find out which of the bacteria actually live in freshwaters – there are only some species or groups. We concentrate on two groups, betaproteobacteria and actinobacteria, which are typical for freshwaters (including those of Central Europe). We use molecular methods, based on the study of the genetic information of the bacteria. We have achieved considerable success in isolating and cultivating aquatic bacteria using unique methods developed by our researchers. Aquatic bacterial biogeography is a very young field and basic investigations on where different bacterial groups occur and why begun only recently.. Our research workers are contributing significantly to its development. We also study the unique microbial communities in acidified Bohemian Forest lakes as well as the development of microbial populations in a lake emerging in a former brown-coal quarry which is being inundated. The study of the functions of aquatic bacteria (the types of organic substances they decompose and utilise, how quickly they grow) and of bacteria in relation to other organisms (protozoa and small animals feed on them and viruses attack them) is a classical field within aquatic microbiology. We have made significant contributions to the currrent general trend in this field: attempts at maximum distinguishment of the individual species or taxonomic groups of bacteria and protoza involved in the processes studied. The work of professor Karel Šimek (one of the most cited Czech ecologists) in this field is especially valued by the international scientifc community. He has contributed significantly to understanding the relationships between bacteria, protoza, and viruses: the protoza influence the composition of bacterial

sladkovodních bakterií studujeme jaké bakterie vůbec ve vodách žijí – jsou to jen určité druhy nebo skupiny. Soustřeďujeme se na dvě typické skupiny sladkých vod (včetně našich): betaproteobakterie a aktinobakterie. Používáme molekulární metody, založené na studiu genetické informace bakterií. Významné úspěchy jsme dosáhli při izolaci a kultivaci vodních bakterií unikátními metodami, vyvinutými našimi pracovníky. Biogeografie vodních bakterií je obor teprve shromažďující základní poznatky (kde se které bakterie vyskytují a proč) a naši pracovníci významně přispívají k jejímu rozvoji. Studujeme také unikátní

Field measurement of microbial parameters at the Medard, an abandoned flooded coal mine pit. / Terénní měření mikrobiálních parametrů na zatopeném důlním jezeru Medard. Foto P. Znachor

mikrobiální společenstva v okyselených šumavských jezerech a vývoj mikrobiálního osídlení jezera vznikajícího v zaplavovaném hnědouhelném lomu. Mezi klasické obory vodní mikrobiologie patří studium funkce vodních bakterií (jaký typ organických látek rozkládají a využívají, jak rychle rostou) a jejich dalšího osudu ve vodním prostředí (bakteriemi se živí prvoci a drobní živočichové a napadají je viry). Současným obecným trendem, ke kterému přispíváme významnými poznatky, je dovedení tohoto studia na co nejvyšší úroveň taxonomického rozlišení (jednotlivé druhy či skupiny bakterií a prvoků). Ve světě jsou ceněny zejména práce profesora Karla Šimka (jenž patří mezi nejcitovanější české ekology), které zásadně přispívají k pochopení vztahů mezi bakteriemi, prvoky a viry: prvoci ovlivňují složení bakterií tím, že upřednostňují jako potravu různé druhy, typy, nebo velikosti bakterií. Tím se mění rychlost přenosu organické hmoty potravními řetězci přes zooplankton až k rybám.

communities by preferential feeding on certain species, types or sizes of bacteria. This changes the rates of transfer of organic matter in the food chain via the zooplankton all the way up to the fish.

The **phytoplankton ecology group** focuses on the research of phytoplankton (consisting of microscopic algae and cyaonobacteria) in terms of their **taxonomy, ecology, ecophysiology, and interaction with bacteria**. Internationally, our institute is one of the most respected research centers dealing with the taxonomy of cyanbacteria (also known as blue-green algae), which are known for their tendency to create unpleasant and dangerous water blooms. The aim is to describe and reliably distinguish individual species using a combination of classical (microscopy) and modern (molecular) methods. Our institute hosts a unique collection of several hundred strains of cyanobacteria and algae isolated from various types of freshwaters. In the field of phytoplankton ecology we try to identify factors responsible for given species or groups of algae or cyanobacteria being in a given place and given time. We study competition for resources between phytoplankton species and the influence of extreme rainfall on the taxonomic composition of phytoplankton communities and on the differences between phytoplankton composition in different reservoir areas. We also focus on long-term changes in phytoplankton composition caused by global climate change. In algal and cyanobacterial ecophysiology, we concentrate on the relationship beween the physiological traits of individual species and their occurence in an aquatic ecosystem. Here our development and implementation of modern fluoresecent methods has gained us a considerable international reputation. The methods consist of marking cells using special fluorescent labels. This then enables microscopic comparison of the qualities of individual cells, such as producion of certain substances, growth rates, cell damage or vitality. Research on the interaction of phytoplankton and bacteria is focused on factors influencing the production of organic substances by phytoplanton and their impact on the composition, activity, and growth of bacteria.

Lake Medard, an abandoned flooded coal mine pit near Sokolov. / Zatopené důlní jezero Medard na Sokolovsku.

Skupina **ekologie fytoplanktonu** se zabývá výzkumem mikroskopických řas a sinic (tj. souhrnně fytoplanktonem) z hlediska jeho **taxonomie, ekologie, ekofyziologie a interakce s bakteriemi**. V taxonomii sinic, známých jejich schopností tvořit nepříjemné a nebezpečné vodní květy, patří naše oddělení mezi významná světová pracoviště. Cílem je popis a spolehlivé rozlišení jednotlivých druhů za použití kombinace klasických (mikroskopie) a moderních přístupů (molekulární metody). Na našem pracovišti se nachází unikátní sbírka několika set kmenů sinic a řas izolovaných z různých druhů sladkých vod. V ekologii fytoplanktonu hledáme faktory zodpovědné za to, že se dané druhy nebo skupiny řas či sinic vyskytují v daný čas na daném místě. Studujeme kompetici mezi druhy fytoplanktonu (soutěž o zdroje), vliv extrémních srážek na složení fytoplanktonu a na jeho rozdílnost v různých místech údolních nádrží, a dále dlouhodobé změny ve složení fytoplanktonu v závislosti na globální změně klimatu. V ekofyziologii řas a sinic hledáme vztahy mezi vlastnostmi jednotlivých druhů a jejich schopností uplatnit se ve vodním ekosystému. Máme významné postavení v používání a vývoji moderních fluorescenčních metod, umožňujících označit buňky speciálními svítícími značkami a v mikroskopu na základě toho srovnávat vlastnosti jednotlivých buněk (produkci určitých látek, rychlost růstu, neporušenost či životaschopnost). Při studiu interakce fytoplanktonu a bakterií jde o výzkum faktorů ovlivňující produkci organických látek fytoplanktonem a jejich vliv na složení, aktivitu a růst bakterií.

Department of Fish and Zooplankton Ecology

The research at the Department of Fish and Zooplankton Ecology is focused on the highest trophic levels in freshwater ecosystems – animal plankton (called zooplankton) and fish. As both trophic levels require different methodological approaches, the department is divided into two specialised laboratories.

Emptying gillnets with a rich catch of young-of-the-year fish. / Vybírání tenatových sítí s bohatým úlovkem tohoročních ryb. Foto J. Kubečka.

The **laboratory of zooplankton ecology** studies mainly crustaceans in large deep lentic waterbodies, in the case of the Czech Republic especially in dam impoundments (reservoirs) and lately also in new artificial lakes in former brown-coal quarries. We especially focus on filtering zooplankton, which, though often called herbivorous, filters not only phytoplankton, but all particles dispersed in water including detritus and bacterioplankton. The key species here is the Cladoceran genus *Daphnia*, which is also a substantial and preferred food resource for planktivorous fish and as such forms an important link in the food pyramid. A basic principle of our work is the combination of field and laboratory approaches, where working hypotheses for laboratory experiments grow out of data obtained via fieldwork. Currently our work falls into five research areas:

- Studies of the interactions between trophic status, fish, and zooplankton in terms of the influence on the species and size composition, and space-time distribution of zooplankton.
- Analyses of long-term changes in the zoplankton of a model reservoir.
- Genetic studies of the populations of the most common European hybrid

Oddělení ekologie ryb a zooplanktonu

Předmětem zájmu oddělení eklogie ryb a zooplanktonu je výzkum nejvýše postavených trofických úrovní ve sladkovodních ekosystémech – živočišného planktonu (označovaného jako zooplankton) a ryb. Protože obě studované trofické úrovně vyžadují odlišné metodické přístupy je oddělení tvořeno dvěma specializovanými laboratořemi.

Předmětem studia **laboratoře ekologie zooplanktonu** jsou hlavně planktonní korýši velkých a hlubokých nádrží, v našich podmínkách především přehradních nádrží a v poslední době také nových typů nádrží vznikajících zatopením důlních jam. Zvláštní pozornost je věnována filtrujícímu tzv. herbivornímu zooplanktonu, který však je schopen filtrovat nejen fytoplankton, ale obecně částice rozptýlené ve vodě včetně detritu a bakterioplanktonu. Jedná se zejména o perloočky rodu Daphnia, které zároveň jako významná a preferovaná složka potravy planktivorních ryb tvoří důležitý spojovací článek v potravní pyramidě. Základním principem práce je kombinace terénních a laboratorních přístupů, kdy pracovní hypotézy pro laboratorní experimenty vycházejí z poznatků získaných při terénních sledováních. V současné době se v zaměření laboratoře kombinuje pět výzkumných rovin:

- Studie interakcí úživnosti, ryb a zooplanktonu ve smyslu ovlivňování druhového i velikostního složení a časoprostorové distribuce zooplanktonu.
- Analýzy dlouhodobých změn v zooplanktonu modelové nádrže.
- Genetické studie populací, v Evropě nejrozšířenějšího, hybridního komplexu D. longispina a vazeb na abiotické a biotické faktory.

Juvenile pike (Esox lucius) over rich overgrowth of Nitella, Chabařovice Lake. / Juvenilní štika obecná (Esox lucius) nad bohatými zárosty skleněnky rodu Nitella, jezero Chabařovice. Foto J. Peterka.

Collecting the early juveniles of zander (Sander lucioperca) from trawl catch dominated by perch (Perca fluviatilis), Římov Reservoir. / Vybírání časných juvenilů candáta obecného (Sander lucioperca) z úlovku plůdkové vlečné sítě dominovaného okouny říčními (Perca fluviatilis), nádrž Římov. Foto J. Peterka.

complex *Daphnia longispina* and of their links to biotic and abiotic factors.

- Research on the „priority effect" of newly colonised biotopes of lakes in former coal quarries and subsequent confrontation with changes caused by fish colonisation.
- Research on the physiological, ecological, and morphological adaptations adaptations of the most common species *Daphnia galeata*, which demonstrates exceptional plasticity.

The main research topics of the second laboratory, the **Fish Ecology Unit (FishEcU)**, are the spatial distribution, behaviour, trophic activity, numbers, and biomass of fish in large inland waters, especially lakes and reservoirs. We study the zoology, ecology and ethology of fish communities and link our findings to other components of the aquatic ecosystem. Our results serve to deepen general knowledge about fish and their role and influence within the whole aquatic ecosystem as well as providing qualified advice and support to practitioners managing fish stocks in lentic water environments.

We place great emphasis on research and development of methods for quantitative sampling of fish stocks. These include horizontal acoustic methods, gauging their limitations, determining the relationships between fish size and the strength

- Výzkum výhody zakladatele (priority effect) nově kolonizovaných biotopů jezer po těžbě uhlí a následné konfrontace se změnou prostředí po kolonizaci rybami.
- Výzkum fyziologicko-ekologických a morfologických adaptací nejběžnějšího druhu Daphnia galeata, vykazujícího mimořádnou plasticitu.

Hlavní náplní **laboratoře ekologie ryb (FishEcU – Fish Ecology Unit)** je výzkum ryb ve velkých vnitrozemských vodách, zejména údolních nádrží a jezerech, se zaměřením na odhalení zákonitostí v rozmístění, chování, potravní aktivitě, početnosti a biomase ryb. V této oblasti pokrývá studium všechny aspekty dané problematiky, tj. zoologii, ekologii a etologii ryb se zřetelem na provázání s dalšími složkami vodního ekosystému. Získané poznatky slouží jednak k prohloubení znalostí o rybách a jejich roli a vlivu na celý vodní ekosystém, a jednak jsou využívány pro návrhy managementu rybích obsádek ve stojatých vodách.

European catfish (Silurus glanis) captured using electrofishing, Římov Reservoir. / Úlovek sumce velkého (Silurus glanis) pomocí hlubinného agregátu, nádrž Římov. Foto M. Říha.

Značné úsilí je věnováno výzkumu a vývoji metod pro kvantitativní vzorkování rybích obsádek. Jde hlavně o aplikace horizontálních akustických metod, odhalování jejich limitací, zjišťování vztahů mezi velikostí ryb a síly jejich akustického ozvu, zpřesňování akustické detekce rybích larev a juvenilů, vodních bezobratlých a v neposlední řadě využití akustických metod při výzkumu chování ryb. Vedle akustických metod má laboratoř velkou tradici v používání pasivních a aktivních lovných prostředků. Rozvíjí metody vzorkování elektrolovem, zátahovými, košelkovými, vlečnými

of their acoustic echoes, improving the accuracy of acoustic detection of fish larvae, juveniles, and aquatic invertebrates, and, last but not least, the use of acoustic methods in research of fish behaviour. In addition to acoustic methods our laboratory draws on its tradition of passive and active hunting implements. We are developing sampling methods using electrofishing, beach seining, purse seining, trawling, and gillnetting. For biomanipulative fish removals and studies of fish migration we also use fish traps.

The Fish Ecology Unit has been contributing substantially to clarifying the hitherto little-understood behaviour patterns of fish in large inland water bodies, and their role in the trophic foodwebs of these ecosystems. We focus especially on fish distribution patterns, horizontal and vertical migrations, and the behaviour of fish towards fishing gear (evasiveness of fish and its implications for gear selectivity). We use acoustic monitoring methods, fish labeling, and direct monitoring with videotechnology (operated *in situ* by scuba divers or via remote control). The role of fish can then be assessed both from a "bottom-up" process (food accessibility for fish under different conditions) and a "top-down" process perspective (fish as consumers feeding on organisms from lower trophic levels and the implications for the qualitative composition of these lower levels and for water quality). We use both individual approaches (trophic effectiveness and selectivity) and approaches based on evaluating the impact of the whole fish community – food rations, consumption rates, bioenergetic modeling, etc.

An important aspect of the work of the Fish Ecology Unit is its complex approach: the absolute importance of individual species and size groups is derived by weighing from the total picture of the fish community. This is made possible by a unique combination of quantitative and qualitative sampling methods.

Stocking of maraena whitefish (Coregonus maraena) into Lake Most. / Vysazování násad síha marény (Coregonus maraena) do jezera Most. Foto L. Vejřík.

Electrofishing at the Květoňov Reservoir. / Odlov ryb hlubinným agregátem na nádrži Květoňov. Foto M. Prchalová.

a tenatními sítěmi, pro manipulační odlovy a pro studie migrací ryb využívá též odlovů do vrší a vězenců.

Laboratoř intenzivně přispívá k objasňování vzorců chování ryb ve velkých vnitrozemských vodách, které jsou doposud málo prostudovány, a jejich role v potravních sítích těchto vod. Aktivity laboratoře se zaměřují zejména na poznání vzorců distribuce ryb, horizontální a vertikální migrace, využívání domovských okrsků a chování ryb vůči odlovným prostředkům (únikovost a z toho plynoucí výběrovost). Používány jsou akustické techniky sledování, značení ryb, přímé sledování pomocí videotechniky, potápěči či dálkově ovládaným průzkumníkem (ROV). Role ryb je pak sledována jednak z pohledu „bottom-up" procesů – dostupnost potravy pro ryby za různých podmínek, tak „top-down" procesů – ryby jako konzumenti živící se na nižších trofických úrovních, a konsekvence z toho vyplývající jak pro kvalitativní složení těchto úrovní, tak nakonec kvalitu vody. Jsou uplatňovány jak přístupy individuální – potravní efektivita a výběrovost, tak přístupy založené na zhodnocení vlivu celého společenstva – potravní raciony, bioenergetické modelování atd.

Zásadní vlastností průzkumů prováděných laboratoří ekologie ryb je, že jsou prováděny komplexně, kdy celkový obraz rybího společenstva zohledňuje váženým způsobem absolutní významnost různých druhů a velikostních skupin. Tohoto výsledku je dosahováno unikátní kombinací kvantitativních a kvalitativních metod vzorkování.

Current Research Highlights / Shrnutí nejdůležitějších projektů

The effect of natural dieback of mountain spruce forest on microclimate, chemistry, and biodiversity of terrestrial and aquatic ecosystems

Windthrows and climatic factors have promoted bark beetle (*Ips typographus*) development and large-scale dieback of Norway spruce in the unmanaged parts of the Bohemian Forest (central Europe). In 2004–2007, the ensuing defoliation killed >90% of forest in the Plešné Lake catchment. Windthrows occurred also in the catchments of Čertovo and Laka lakes. All these areas have been subjects of our intensive long-term ecological research (water, climate, soil, and forest) since 1984–2002. Available pre-disturbance data, current research, and new proposed studies provide a unique opportunity for complex ecological research on the effects of natural forest dieback on individual ecosystem parts. This research has recently attracted grant funding to: (1) carry out a mass budget study of changes in element fluxes and pools on a whole-catchment scale (forest, soil, waters); (2) evaluate the effects on microclimate, hydrology, and soil and aquatic chemistry, and biodiversity; and (3) project the net effects to other mountain areas, different forestry practices, and along the anticipated trends in climate and atmospheric pollution. Major hypotheses are:

H1 (terrestrial ecosystem): Natural forest disturbances by bark beetle infestations in areas of unmanaged forest cause significant short-term changes in microclimate, hydrology, and soil nutrient pools and cycling, compared to unaffected forest. But their effects on long-term sustainability, biodiversity, and ecological functions of mountain ecosystems will be lower than those of salvage logging and timber removal.

Lake Plešné in 2010, Šumava mountains, Czech Republic. / Foto J. Kopáček

H2 (aquatic ecosystems): Forest disturbances will strongly affect water nutrient concentrations and toxicity, and thus aquatic biodiversity for several years. The pre-disturbance trend in water recovery from acidification will become re-established relatively soon, but the disturbance-driven loss of base cations will increase ecosystem sensitivity to acidification in the future.

*The research is supported by the Grant Agency of the Czech Republic project No. P504/12/1218 (2012–2016), principal investigator **J. Kopáček** (co-investigators: **H. Šantůčková,** University of South Bohemia), and **M. Svoboda,** Czech Univ. of Life Sciences).*

Effects of solar radiation on biogeochemical cycling of nutrients and metals in surface waters

This grant project focuses on important but poorly understood effects of solar radiation on biogeochemical cycling and availability of nutrients and toxicity of metals in surface waters. The importance of photo-transformations of dissolved organic matter (DOM) may increase in conditions of increased terrestrial export of DOM, high levels of UV radiation, and anticipated climate change, i.e. increase in temperature, precipitation, and cloudiness. The project is expected to answer the following important questions: 1) What proportions of dissolved inorganic carbon and particulate organic carbon (POC) result from DOM photodegradation under different conditions? 2) How efficient is natural solar radiation in changing speciation of organically-bound phosphorus and nitrogen within DOM? 3) To what extent are POC-metal complexes arising from photodegradation of DOM able to bind phosphate?

Ongoing studies indicate that the photodegradation of DOM results in the decrease of molecular weight of organic molecules and in production of carbon oxides. The ratio between photo-production of carbon oxides and particulate organic matter depends on temperature. Production of carbon oxides dominates at lower temperature while formation of particles prevails at higher temperature. In waters with higher contents of organically bound metals, formation of insoluble metal hydroxides causes precipitation of particulate organic matter. DOM photodegradation can also strongly affect phosphorus distribution in the aquatic environment due to its adsorption on newly formed particles.

*The research is supported by the Grant Agency of the Czech Republic project No. P503/12/0781 (2012–2014), principal investigator **P. Porcal.***

Centre for Ecological Potential of Fish Communities in Reservoirs and Lakes (CEKOPOT)

Fish communities in reservoirs and lakes are highly valuable from a genetic, ecological and economical point of view. They also have substantial influence on the water quality in these ecosystems. A new project enables the support of a top quality team for the synthesis of research on the functions mentioned above and for the definition of ecological potential of fish communities. It will also involve the improvement and broadening of current methods and investigation of the fish stock in the most important and interesting reservoirs in the Czech Republic. At the same time, Czech activities will be interconnected with European initiatives in order to make more widely known the huge effort of the Czech limnological school in describing fish communities and their role in aquatic ecosystems. The complex specification of the ecological potential of fish communities, their faunistic, fish-productive and biomanipulative value, population dynamics equlibria and trophic interactions is possible by the support of Czech researchers´ capacities, their internships at top institutions, their integration into European research structures, and through close cooperation with external experts. The engagement of As./Prof. Helge Balk from Norway, a leading expert in hydroacoustics, has enabled method improvement, especially with regards to methods of data collection in shallow water layers (0–5 m). New methodological approaches have been planned – the analysis of stable isotopes in fish which should help us to clarify the role of particular species and their ontogenetical stages in the food webs of the ecosystems studied. Within the framework of the project a field course and an international conference dealing with the function of fish in the reservoir ecosystem will be organized. The main outputs of the grant project will be as follows: I) final establishment and stabilization of the working group „Fish Ecology Group" at the Hydrobiological Institute (FISHECU), II) involvement of the Czech Republic in the European intercalibration net (JRC-EEWAI intercalibration forum, Lake-Fish Intercalibration Group LFIG), III) production of scientific papers, IV) internships abroad for our scientists and students, oriented on hydroacoustics and methods of stable isotope studies.

Financial support: Ministry of Education, Youth and Sport of the Czech Republic administrates the support provided from EU funds, proj. No. CZ.1.07/2.3.00/20.0204, (2012–2015), principal investigators ***J. Matěna, J. Kubečka.***

Get out! she signalized: sex segregation of freshwater fish

Sex segregation is widespread in the animal kingdom. But it has not been investigated much in freshwater fish. The guppy is the only aquatic vertebrate for which the hypothesis of sex segregation has been verified. In an upcoming grant project we will study sex segregation of the five most common fish species in lentic freshwaters in Europe. Using gillnet sampling and segregation coefficient we will be able to say whether fish are sexually segregated and how (habitat vs. location segregation). Three potential reasons for segregation will be tested (predation pressure, water temperature, food availability). Sex dimorphism will be studied in detail as well. Parameters such as life expectancy, growth conditions, length-weight relationship, and morphology of the branchial sieve will be compared between sexes. The females of target species might be more active and be in a better condition, which could bias the representativeness of gillnet sampling. To counter this we plan a simple experiment where gillnet sampling in a rented pond stocked with a completely known fish community in terms of sex ratio and condition will be carried out.

The research is supported by the Grant Agency of the Czech Republic project No. P505/12/P647 (2012–2014), principal investigator ***M. Prchalová.***

Phytoplankton extracellular DOC release

During phytoplankton growth, a significant part of assimilated dissolved inorganic carbon is released by phytoplankton in the form of dissolved organic carbon (extracellular release; ER), which serves as an important and high-quality substrate for aquatic bacteria. The percentage of the total primary production released as organic carbon (PER) is generally considered to increase with nutrient limitation and to decrease with phytoplankton biomass, primary production, and trophic status. Information about the dependence of PER on phytoplankton taxonomic composition, seasonal plankton cycle, and on phytoplankton-bacteria coupling mediated by ER, is still rather scarce and fragmented. At the Department of Aquatic Microbial Ecology, in order to understand interactions between phyto- and bacterioplankton (recently particularly taxon-to-taxon relationships), we study phytoplankton DOC release (EP, PER), using the ^{14}C-method, for the last two decades at the Římov Reservoir. In parallel, we also assess phytoplankton and bacterioplankton composition and a number of background explanatory limnological variables. The most intensive sampling campaigns were conducted in 1999, 2005, and 2009. Currently (2011–2014), the research is supported by a specific grant from the Czech Science Foundation (No P504/11/2182, "Phytoplankton release of dissolved organic carbon and its relationship to bacterioplankton composition").

In the Římov Reservoir, the overall average PER was 8.1% (range 0–30.8%) of total primary production (n=92; 1999–2013). Variables traditionally reported as predictors of PER, e.g. dissolved reactive phosphorus (the limiting nutrient), phytoplankton

biomass and total primary production showed the expected inverse, but only weak (r2≈0.1), relationship to PER fitted with a linear regression. On the contrary, we observed some distinct patterns and found statistically significant relationships, not hitherto reported for natural aquatic systems, regarding seasonality, phytoplankton taxonomic composition, and phytoplankton cell/colony size.

Low PER measured early in the spring, in summer, and in autumn (average PER of 6%, 4%, and 7%; respectively) contrasted with high values found during the spring phases of plankton development (phytoplankton maximum, clear water period, and late spring, with PER averaging at 14%, 16%, and 10%; respectively).

Cryptophytes were the principal phytoplankton group clearly associated with PER. As much as 38% of seasonal variability in PER could be explained by the contribution of this group to the total phytoplankton biomass. Conversely, cyanobacteria and diatoms were obviously associated with low PER as their relative proportion in the phytoplankton was negatively correlated with PER. Typical taxa of spring phytoplankton assemblages such as *Cryptomonas marssonii*, *Rhodomonas minuta*, *Cryptomonas sp.* (cryptophytes), *Chrysochromulina parva* (haptophytes), and *Cyclotella sp.* (diatoms) were associated with high PER (>12%), while summer species *Anabaena crassa*, *Aphanizomenon flos-aquae*, *Woronichinia naegeliana* (cyanobacteria), and *Ceratium hirundinella* (dinophytes) were linked with low PER (<3%; see Fig. 1 for more detailes).

Phytoplankton size was inversely related to PER (r2=0.31), i.e. smaller cells exhibited higher relative DOC release (higher PER). For each sample, we calculated the mean particle size as biomass-weighted average of maximum linear dimension (MLD) of all taxa exceeding 5% of their relative contribution to the overall biomass, and thus the obtained value was related to PER. It is worth noting that MLD tends to increase with the volume/surface ratio (V/S) of particles (for the constant geometric shape this increase is exactly proportional) and that diffusion losses are predicted to decrease with V/S, as observed for PER.

Phytoplankton cell death associated with loss of cell membrane integrity has been reported to accelerate the efflux of small metabolites into water and thus could contribute to the DOC release. Hence, we employed SYTOX Green to test the membrane integrity and estimate the importance of this process. However, no correlation between observed ER and membrane integrity was found.

One may ask how phytoplankton extracellular DOC release (ER) affects bacterioplankton composition. In this respect, our data are rather preliminary as sample processing and data evaluation is still in progress. Of the most important freshwater bacterial groups, the abundance of Actinobacteria was high in the periods of low ER, week positive relationship to ER was found for the group Cytophaga/Flavobacterium, and Betaproteobacteria did not depend on ER at all. For some taxonomically narrow bacterial subgroups, however, we found significant relationships to ER. For instance, the bacterial group RBT (largely identical with the recently described bacterial genus *Limnohabitans*) was clearly associated with high ER. Recently, we obtained promising results by including newly developed genus- or species-like probes from subgroups of Cytophaga/Flavobacterium group (FLAV-A, FLAV-B, FLUV, etc.) and Betaproteobacteria (Pnec-B etc.) to our bacterioplankton analyses. For instance, the abundance of bacteria affiliated to Pnec-B was positively correlated with ER and its peaks were mostly associated with the presence of the alga *Staurastrum planctonicum* (Desmidiaceae). The subgroups FLAV-A and FLAV-B were clearly associated with high ER and often concurred with *Cryptomonas sp.* and *Chrysochromulina parva*, respectively. The subgroup FLUV was related to low ER and peaked mainly in the periods when the diatom *Fragilaria crotonensis* dominated.

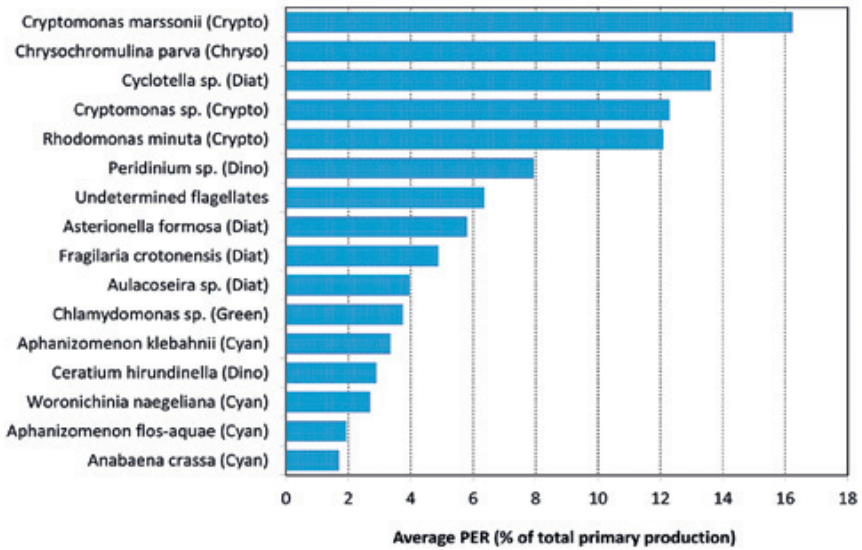


Fig. 1. Average values of PER (percent extracellular production; i.e. the percentage of the whole assemblage primary production released as DOC) associated with the presence of common phytoplankton taxa in the Římov Reservoir. The samples, where the contribution of a given taxon to the total phytoplankton biomass exceeded 25%, were taken into account. PER values measured in these samples were averaged and plotted in the graph.

Recent Research Outputs / Vybrané výsledky

Catchment ecology responding to past and future changes

There is a number of global drivers acting on surface water quality and aquatic ecosystems, including changes in land use, water resource requirements, atmospheric pollution, and climate change. In the EU 7th FP project REFRESH (Adaptive Strategies to Mitigate the Impacts of Climate Change on European Freshwater Ecosystems) we were concerned with what was the history of the water quality and ecology of rivers and lakes, and how will these change within the next half-century (till 2060), in particular in the context of compliance with the EU Water Framework Directive (WFD). We were also concerned with what management measures can be taken that will account for future change and whether the costs incurred are cost effective, proportionate and have other benefits. Case studies were done at six study catchments across the European climate gradient, from Nordic countries to Greece, where scenario analyses were undertaken to see what climate, land use, water resource, demand, and pollution pressures may be imposed in the future and how this will affect the chemical and ecological indicators in rivers and lakes.

In the Czech Republic, we did a series of studies in the upper River Vltava catchment as a representative of Central European conditions to evaluate sources of nutrients (nitrogen, phosphorus, sulphur) and their transport via the river network into receiving water bodies where they influence water quality and eutrophication [1,2,3,4]. Using a model chain comprising of a hydrological model, catchment-scale models for phosphorus and nitrogen biogeochemistry (INCA-N,P), and a lake stratification and aquatic ecosystem model (CE-QUAL-W2), we analysed the impacts of future climate change and various potential trends in socio-economic development in the catchment on nutrient status and eutrophication of surface waters and also to suggest cost-optimum measures for achieving compliance of currently too high phosphorus concentrations in the runoff from the catchment with WFD standards for good ecological status. The climate change that was predicted till 2060 using three regional climate models, showed well discernible effects on seasonal patterns of river flow and nutrient concentrations in stream and lakes, however, the impacts were low when compared to much larger influences of human activities and land use in the catchment. The best cost-effective set of mitigation measures to decrease phosphorus concentrations below the WFD standards included a high-efficiency P removal at most wastewater treatment plants combined with phosphorus-balanced fish production in fishponds and reduction of P losses from agricultural areas. However, these mitigation measures were shown to be problematic to realize during consultations with major stakeholders of the catchment, due to their high costs and inconsistencies in the national legislation in the water management and surface water quality regulations [5].

[1] Kopáček J., Posch M., Hejzlar J., Oulehle F., Volková A. 2012: An elevation-based regional model for interpolating sulphur and nitrogen deposition. Atmospheric Environment 50: 287–296.

[2] Kopáček J., Hejzlar J., Posch M. 2013: Quantifying nitrogen leaching from diffuse agricultural and forest sources in a large heterogeneous catchment. Biogeochemistry 115: 149–165.

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[4] Kopáček J., Hejzlar J., Porcal P., Posch M. 2014: Sulphate leaching from diffuse agricultural and forest sources in a large central European catchment during 1900–2010. Science of the Total Environment 470–471, 543–550.

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The Orlík dam on the River Vltava. / Přehradní nádrž Orlík.

Projekt GA ČR 526/09/0567
Integrated effects of climate change, atmospheric pollution, and forest management on headwaters aquatic ecosystems.

This project was focused on integrated forest, hydrological, atmospheric, and limnological research of headwater catchments existing on gradients from highland to alpine regions (lakes in the Tatra Mountains and Bohemian Forest and streams in the Jizera and Brdy Mountains). The major hypothesis was that similar changes in terrestrial parts of the ecosystem would have different effects on soil and water chemistry and biota in different mountain regions, due to their different land-use history, N-saturation, and cumulative extent of historical acidic deposition.

Duration: 2009–2013

Investigator: E. Stuchlík, Faculty of Science, Charles University in Prague

Co-investigator: J. Kopáček, Biology Centre ASCR

Within 26 peer-reviewed articles published during this project, 14 appeared in SCI journals, and 2 as book chapters. Twenty-two contributions were published in conference proceedings. The major results based on research done in Biology Centre ASCR are as follows:

1) Studies in the Bohemian Forest and the Tatra Mountains confirmed a fundamental role of vegetation cover for cycling of nutrients and pollutants (input, retention, export) in catchments (Kopáček et al. 2009a, 2011a), and highlighted differences in phosphorus retention in forest vs. alpine, and acidified vs. non-acidified soils (Kaňa et al. 2011).
2) Significant differences in phosphorus and organic carbon sources for water ecosystems were described along elevation (temperature) gradients in the Tatra Mountains (Kopáček et al. 2011b), as well as during climatic changes in the Bohemian Forest (Kopáček et al. 2009b).
3) Changes in the soil quality affect export of organic matter and Al-organic complexes from catchments, and subsequently, also concentrations of toxic Al forms in surface waters, which originate from photochemical cleaving of the Al-organic complexes (Kopáček et al. 2009b).
4) Water retention time in soils influences the extent of immobilisation (reduction) of sulphate, as well as its mobilisation (oxidation of reduced S forms), and thus a hysteresis in leaching of sulphate, and recovery of terrestrial systems from acidification (Kopáček et al. 2014).
5) Nitrate leaching from forest watersheds depends on the level of their N saturation, which is determined by the health status of forest stands and N deposition (Kopáček et al. 2012). An important factor is the cumulative N deposition, influencing terrestrial biodiversity (Kopáček and Posch 2011). Besides the estimate of the cumulative N deposition for Europe, the study by Kopáček and Posch (2011) represents the first publication reconstructing global anthropogenic N emissions to atmosphere since the beginning of agricultural revolution (throughout the whole Holocene and industrial period).

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Kopáček J., Hejzlar J., Vrba J., Stuchlík E. 2011b. Phosphorus loading of mountain lakes: Terrestrial export and atmospheric deposition. Limnology and Oceanography, 56(4): 1343–1354.

Kopáček J., Posch M., Hejzlar J., Oulehle F., Volková A. 2012. An elevation-based regional model for interpolating sulphur and nitrogen deposition. Atmospheric Environment, 50: 287–296.

Kopáček J., Hejzlar J., Porcal P., Posch M. 2014. Sulphate leaching from diffuse agricultural and forest sources in a large central European catchment during 1900–2010. Science of the Total Environment, 2014, 470–471: 543–550.

Projekt GA ČR GAP504/11/2177
The importance of cell death for freshwater phytoplankton succession, structure and composition
PI: Petr Znachor

Phytoplankton constitute an important component of pelagic food webs in freshwater reservoirs. For a better understanding of phytoplankton dynamics, it is crucial to know the processes that affect both increase and decline of a population. Traditionally, grazing and sedimentation have been considered as the main factors responsible for reducing size of natural phytoplankton population. Recently, cell death was recognized as an additional and important loss process. To assess the significance of cell death in phytoplankton, we studied cell viability of dominant species in the lacustrine and transition zones of the Římov Reservoir. We used the membrane-impermeant

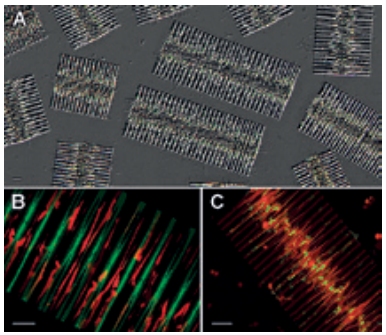


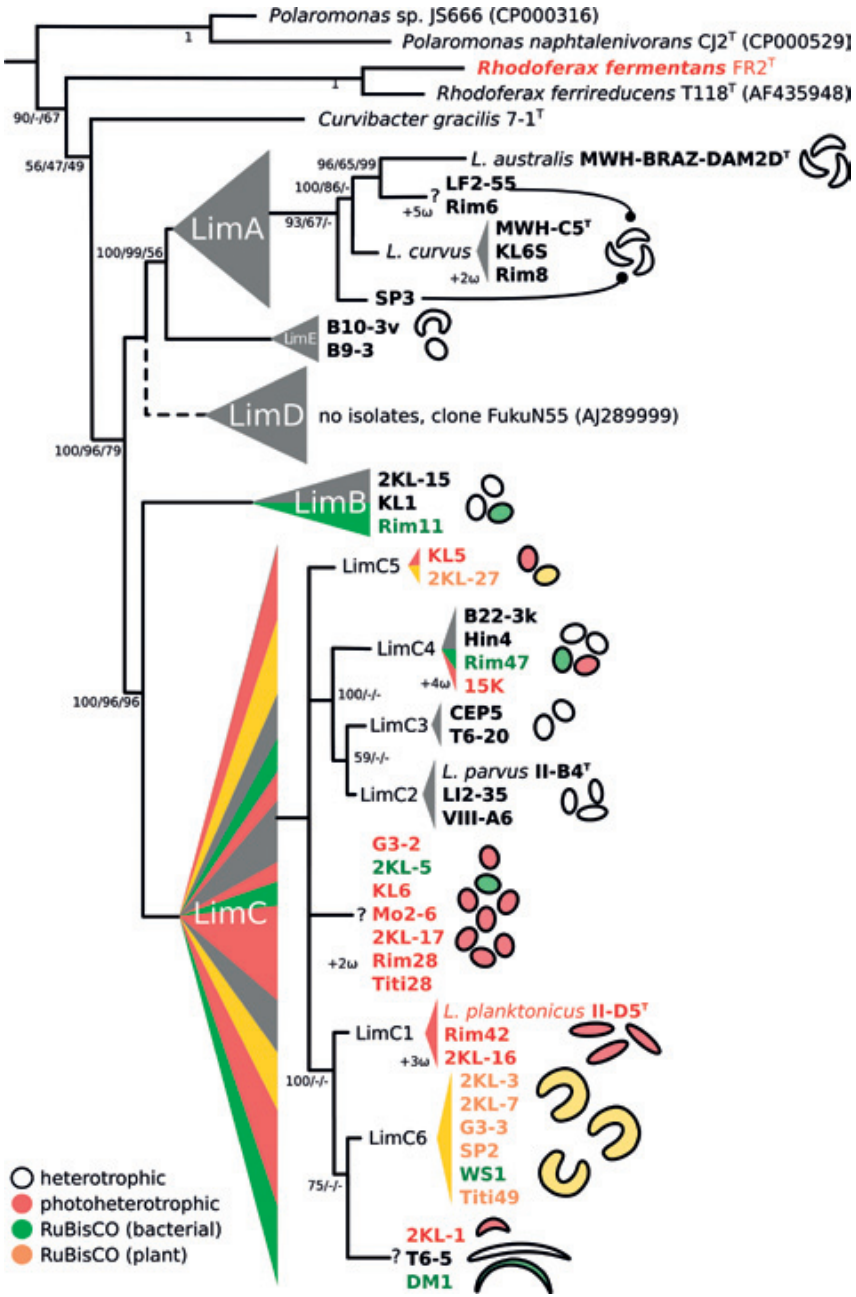
Figure 1: Microscopic images of a colonial diatom Fragilaria crotonensis. A: Nomarski differential contrast, B: composite image of chlorophyll autofluorescence (red) and specific Si tracer in diatoms – PDMPO (green), C: composite image of chlorophyll autofluorescence and SYTOX Green, the membrane integrity probe staining nuclei of non-viable cells (green). Scale bar 10 µm.

nucleic-acid dye SYTOX Green to examine spatiotemporal differences in phytoplankton cell viability. Our results indicate that considerable inter- and intra-species variation in cell viability is common in a freshwater environment. In particular phytoplankton taxa, the importance of cell death may vary both seasonally and along the longitudinal profile of the reservoir. As a result of low light availability, some taxa displayed marked decrease in cell viability (cyanobacteria) with depth while the other did not (diatoms).

To obtain deeper insight into the processes driving changes in the population size, we used two fluorescence techniques to measure growth (PDMPO) and viability (SYTOX Green) of a dominant diatom *Fragilaria crotonensis*. Fragilaria growth and viability were found to be driven by different factors. *Fragilaria* growth rates were tightly related to physical properties of the environment, specifically daily light exposure and inflow rates. Fragilaria viability in contrast, declined markedly with decreased ambient silica concentration. This indicates that while diatom growth is tightly related to physical properties of the environment, cell viability reflects the availability of silica, which is essential for generating and maintaining diatom siliceous frustules. Importantly, there was a significant negative correlation between Fragilaria viability and growth, suggesting that seasonal peaks of diatom growth are coupled with low cell viability.

Genomic studies of the bacteria affiliated within the *Limnohabitans* genus

Genus Limnohabitans represents an environmentally important group of bacteria inhabiting freshwater limnic habitats (Šimek et al. 2001, Šimek et al. 2010). Its representatives were shown to be an active component of the freshwater microbial loop with high uptake rates of various organic carbon sources on one side (Salcher et al. 2011) and with high grazing-related mortality on the other side (Šimek et



al. 2005). To determine well-defined ecological units of the *Limnohabitans* genus, it is of the primary interest to study their physiological traits and metabolic potential. After a morphologic and a phylogenetic revision of the genus *Limnohabitans* (Kasalický et al. 2013) we selected 12 representative strains from different sub-lineages of the genus *Limnohabitans* for further genome analyses.

Draft genomes (including all 4 described type-strains, i.e. *L. planktonicus*, *L. parvus*, *L. curvus* and *L. australis*) revealed that *Limnohabitans* members belong to the mid-sized bacteria with a genome size from 2.6 Mbps to 5.1 Mbps. They have from 2,500 to 4,700 open reading frames (ORFs) and share more than 80 % of annotated traits ranged in subsystems (i.e. more than 1680). Major part of the coding genes belong to the category of the synthesis and metabolism of amino acids, carbohydrates, proteins, fatty acids and vitamins. Large part of genes is dedicated to membrane transport and nucleic acids metabolism. Sulfur oxidation has been found as the basic metabolic feature common to all sequenced *Limnohabitans* strains. Together with their fermentation capacity, they have an efficient tool to receive energy under the anoxic conditions.

Three different types of the energetic metabolism – heterotrophic, photoheterotrophic, and mixotrophic (CO_2-fixation), have been found within the *Limnohabitans* genus (Figure 1). Whole genome sequencing showed the existence of whole photosynthesis gene cluster (PGC) and complete set of genes for CO_2-fixation in respective strains. Moreover, a thorough screening among all available isolated strains revealed phylogenetic clues of bacterial photosynthesis within the genus *Limnohabitans*. It seems most probable that photosynthesis was at the origin of the genus differentiation as the evolution of the PGC underwent similar phylogenetic history to the ribosomal genes. Contrary, the RuBisCO gene(s) were most likely acquired by two (or more) independent horizontal gene transfers. We have found two forms of RuBisCO, type I and type II, closely related to sulfur-oxidating bacteria but having diverged much earlier from each other. Their presence is only rare within the genus *Limnohabitans* and it has been found only in strains with PGC. The small-sized morphotypes of the heterotrophic members present in both lineages probably lost their PGC during the genome streamlining process. The lack of PGC in the large morphotypes could be the result of a life-style shift.

Studying in situ life-style of a given group of microbes is indeed problematic. Providing a comprehensive study of any type of biological diversity would be complicated beyond feasibility if nearly every individual organism was ecologically unique. Our studies shows that this is not the case with the genus *Limnohabitans*. With a deeper analyses of the genomic traits we will be able to attribute the physiological properties to individual genotypes. For example, further screening for photosynthesis genes will help us to understand the role of light in the energetic demand of the bacteria.

Figure 1. Completely heterotrophic lineages LimA and LimE lack both photosynthesis and CO_2-fixation genes. Contrary, bacteria with all three metabolism types are present in lineages LimB and LimC.

Genus *Limnohabitans*, an important freshwater bacterial group, serves as a model for testing responses of natural flagellate communities to different bacterial food quality

One of the core research lines of the Department of Aquatic Microbial Ecology (HBI) are studies, in collaboration with colleagues from Austria, Germany and France, dealing with the occurrence, ecophysiology, taxonomy and the role of bacteria of the genus *Limnohabitans* in carbon transfer to higher trophic levels [1–5]. *Limnohabitans* bacteria are abundant in circumneutral or alkaline lakes [1] and they display high growth rates, with a notably tight relationship to algal-derived organic substances [6,7]. Their large growth potential and biomass are counterbalanced by a marked vulnerability to protist grazing [4,8]. These ecological traits, together with the fact that strains representing different lineages of the genus *Limnohabitans* have recently

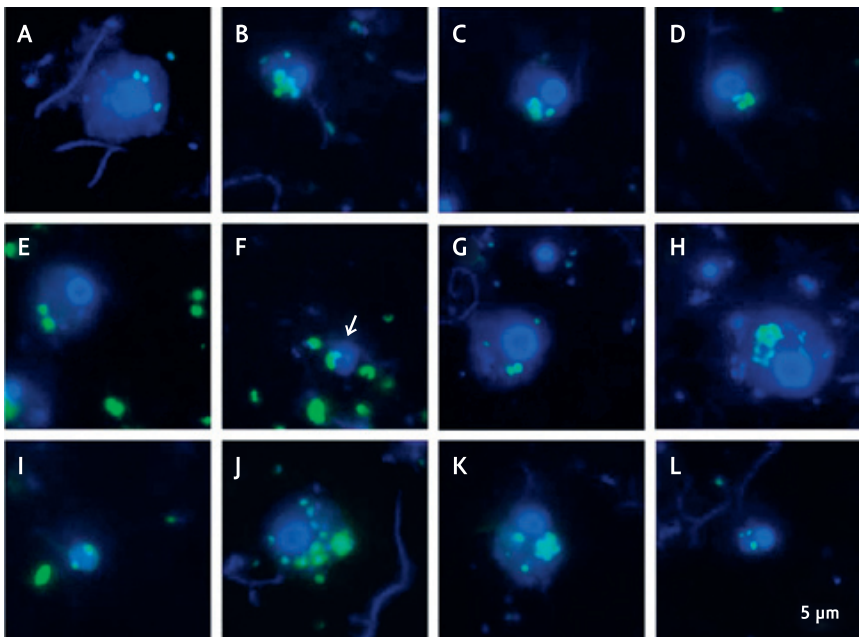


Figure 1. *Microphotographs of bacterial populations and HNF bacterivory in different bacterial treatments shown as overlay images (DAPI- and FITC-stained) of prey bacteria targeted by FISH probes in food vacuoles of HNF. All Limnohabitans strains were targeted by the R-BT065 probe, L. parvus (A, B), L. planktonicus (C, D), 2KL-1 (E, F), 2KL-27 (G, H); the MoIso2 strain was targeted by the Pnec-B-23S-166 probe (I, J); and the actinobacterial Wo1 strain was targeted by the HGC69a probe (K, L). A white arrow indicates the position of a typical large solenoid cell of the 2KL-1 strain ingested in HNF food vacuole. The scale bar shows 5 µm.*

been isolated [3], make this bacterial group an invaluable model for testing its role in carbon flow to higher trophic levels.

Most notably, different bacterial strains can have different nutritional value as food for heterotrophic nanoflagellates (HNF), thus modulating HNF growth and community composition. We proposed an innovative experimental design to examine the influence of prey food quality using four *Limnohabitans* strains, one *Polynucleobacter* strain and one freshwater actinobacterial strain (Luna 2 cluster) on growth (growth rate, length of lag phase, and biomass yield) and community composition of a natural HNF community from a freshwater reservoir [5]. Pyrosequencing of eukaryotic SSU rRNA amplicons was used to assess prey-related changes in HNF community composition. All *Limnohabitans* and *Polynucleobacter* strains yielded significant HNF community growth while the actinobacterial strain did not support HNF growth though it was clearly detected in flagellate food vacuoles, **Fig. 1**. Notably, even within the *Limnohabitans* strains we found significant prey-related differences in HNF growth parameters, which could not be explained only by the size or shape of the bacterial prey.

Sequence data characterizing the HNF communities showed also that not only very different strains but even closely related bacterial prey items induced highly significant differences in the resulting community composition of flagellates. Generally, phylotypes from *Chrysophyceae* closely related to *Pedospumella* or *Spumella*-like subclusters D and E2 were the most abundant bacterivorous flagellates rapidly reacting to addition of bacterial prey of high food quality. Overall, our experimental approach combined with pyrosequencing of the grazer community could provide important insights regarding the question which bacterial strains are active in carbon transfer to the grazer food chain in a particular aquatic system, and which flagellate groups are the key players in the trophic transfer [5]. To the best of our knowledge, our recent study in the ISME Journal [5] is the first such study clearly documenting strong prey-specific effects of even closely related bacteria on HNF community composition. While this ecological aspect has long been debated, direct evidence for natural HNF assemblages had previously been missing.

This research is currently supported by the Grant Agency of the Czech Republic project No. 13-00243S (2013–2017), principal investigator ***K. Šimek.***

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Data and Statistics

Regular monitoring of the reservoirs Slapy and Římov: dissolved and dispersed substances in reservoir water

Annual and summer (April-September) mean concentrations of chemical constituents dissolved and dispersed in the surface layers of the Slapy and Římov reservoirs (**Table 1**) were summarized by ***J. Hejzlar*** and ***J. Kopáček***. Samples were taken from 0.1 to 0.4 m depth at the deepest points of the reservoirs in three-week intervals, pre-filtered through a 200-µm polyamide sieve to remove large zooplankton, stored in the dark at 4 °C, and analysed within 48 h after sampling. Dissolved constituents were analysed in samples filtered through a glass fibre filter with 0.4 µm nominal pore size. Abbreviations in **Table 1** are: TON, total organic nitrogen; DON, dissolved organic nitrogen; TN total nitrogen; TP, total phosphorus; TDP, total dissolved phosphorus; COD, chemical oxygen demand; DOC and POC, dissolved and particulate organic carbon, respectively.

Table 1: Annual (n = 17) and summer (April–September; n = 9) mean composition of surface waters of Slapy and Římov reservoirs in 2012

VARIABLES	UNIT	MEAN VALUES			
		Slapy		Římov	
		Annual	Summer	Annual	Summer
NO_3-N	µg l^{-1}	2476	2613	1233	1011
NO_2-N	µg l^{-1}	25	36	8.9	11.7
NH_4-N	µg l^{-1}	50	42	32	37
TON	µg l^{-1}	874	1020	585	625
DON	µg l^{-1}	736	779	497	518
TN	µg l^{-1}	3425	3711	1858	1685
TP	µg l^{-1}	62.2	49.1	32.6	27.2
TDP	µg l^{-1}	41.6	24.6	21.9	16.1
COD	mg l^{-1}	26.9	29.0	20.3	23.1
DOC	mg l^{-1}	7.79	8.03	5.40	5.68
POC	mg l^{-1}	0.87	1.32	0.64	0.81
Ca^{2+}	mg l^{-1}	19.8	20.4	10.5	10.4
Mg^{2+}	mg l^{-1}	5.9	6.2	2.7	2.7
Na^{+}	mg l^{-1}	9.6	9.4	6.0	5.8
K^{+}	mg l^{-1}	3.9	3.8	2.1	2.0
SO_4^{2-}	mg l^{-1}	25.7	28.2	14.1	14.1
Cl^{-}	mg l^{-1}	13.8	13.8	5.8	5.5
Alkalinity (Gran titration)	meq l^{-1}	0.92	0.89	0.52	0.52
Conductivity at 25 °C	µS cm^{-1}	215	216	118	114

Regular monitoring of the reservoirs Slapy and Římov: microbial characteristics, chlorophyll and zooplankton

Annual and summer mean concentrations of bacteria, protozoans, microzooplankton, BOD_5 (total and after separating algae by filtration) as well as chlorophyll concentrations and zooplankton in the reservoirs (and inflows to Římov Reservoir), based on data by ***M. Kaňová, M. Macek, R. Malá, Z. Prachař, J. Seďa, K. Šimek, M. Šorf, M. Štojdlová, V. Straškrábová*** (*vierastr@gmail.com*), *and* ***P. Znachor*** are shown in **Table 2**.

Table 2: Mean values of microbial characteristics, zooplankton, chlorophyll a and BOD in the Slapy and Římov Reservoirs and inflows. „Summer": April to September. Sites: S-Slapy and R-Římov Reservoirs, C-Černá and M-Malše rivers – inflows to Římov Reservoir. Zooplankton was not sampled in January – March in Slapy and in January in Římov.

SITE	VARIABLE	LAYER	UNIT	MEAN VALUE	
				Annual	Summer
S	BOD_5	0 m	mg l^{-1} O_2		2.85
	BOD_5 filtered	0 m	mg l^{-1} O_2		2.11
	bacteria DAPI	0 m	10^6 ml^{-1}	3.96	6.04
	het. nanoflag.	0 m	10^3 ml^{-1}	1.86	2.98
	chlorophyll *a*				
	total	0–3 m	mg m^{-3}	7.53	14.59
	zooplankton abundance				
	Cladocera herbiv.	0–41m	10^3 ind m^{-2}	350.3	364.3
	Copepoda adult	0–41m	10^3 ind m^{-2}	45.1	81,2
	total crustaceans adult	0–41m	10^3 ind m^{-2}	296.4	447.5
R	BOD_5	0 m	mg l^{-1} O_2	1.97	2.08
	BOD_5 filtered	0 m	mg l^{-1} O_2		1.47
	bacteria DAPI	0 m	10^6 ml^{-1}	4.01	5.70
	het. nanoflag.	0 m	10^3 ml^{-1}	2.85	4.04
	ciliates	0–4 m	per ml	1.11	1.19
	chlorophyll *a*				
	total	0–4 m	mg m^{-3}	7.86	12.21
	> 40µm	0-4 m	mg m^{-3}	3.35	6.20
	zooplankton biomass, protein N				
	Cladocera herbiv.	0–40 m	mg m^{-2}	109.3	117.8
	Copepoda	0–40 m	mg m^{-2}	35.3	38.1
	total crustaceans	0–40 m	mg m^{-2}	148.0	160.4
C	BOD_5	0 m	mg l^{-1} O_2		1.57
	chlorophyll *a*	0 m	mg m^{-3}	3.82	5.12
M	BOD_5	0 m	mg l^{-1} O_2		2.04
	chlorophyll *a*	0 m	mg m^{-3}	4.49	6.26

Projects

European Communities R&D program (7th framework)

2010–2014 Reg. code 244121, Adaptive strategies to mitigate the impacts of climate change on European freshwater ecosystems (J. Hejzlar)

Projects financed by the Ministry of Education, Youth and Sports of CR

2011–2014 Reg. code CZ.1.07/2.4.00/17.0130, Interdisciplinary network of cooperation for policy development for sustainable development (J. Vrba)

Projects financed by the State Environmental Fund of the Czech Republic

2012–2014 Reg. code 05611212 Methodology for evaluation of the reservoir ecological potential (J. Borovec)

Projects financed by the Ministry of Agriculture of CR

2010–2013 Reg. code QI102A265, Determination of the importance of erosion-originated phosphorus in water bodies endangered by eutrophication (J. Hejzlar)

Projects financed by the Grant Agency of CR

2009–2013 Reg. code 206/09/0309, Competition mechanisms in Cyanobacteria affecting phytoplankton species composition (K. Řeháková)

2009–2013 Reg. code GA526/09/0567, The integrated impact of climate change, air quality, and forest management on water ecosystem in headwater catchments (J. Kopáček, coordinated by Faculty of Science UK, Praha)

2010–2013 Reg. code EEF/10/E011, Functional role and ecotype divergence in Actinobacteria of the AcI lineage (J. Jezbera)

2011–2013 Reg. code P504/11/2177, The importance of cell death for freshwater phytoplankton succession, structure and composition (P. Znachor)

2011–2014 Reg. code P504/11/2182, Phytoplankton release of dissolved organic carbon and its relationship to bacterioplankton composition (J. Nedoma)

2012–2015 Reg. code P504/12/1186, Hydroacoustical distinguishing between fish and bubbles (J. Frouzová)

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2013–2017 No. 13-00243S (K. Šimek)

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2012–2014 Reg. code 264 (přeshraniční spolupráce Cíl 3, ČR–Bavorsko, 2007–2013), Integrated Soil and Water Conservation in the Drachensee Catchment. ERDF – Cíl 3 (Ministerstvo pro místní rozvoj ČR) (J. Žaloudík)

2012–2015 Reg. code CZ.1.07/2.3.00/20.0204, Centre for Ecological Potential of Fish Communities in Reservoirs and Lakes. MŠMT – OPVK (J. Kubečka, B. Helclová)

Consultancies

2012–2013 Complex assessment of the fish community of the Chabařovice post mining lake in 2012. Palivový kombinát Ústí, s.p. (J. Peterka, J. Kubečka)

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2012–2013 Reg. code 2096/2012-SML, A study on water quality of the Lipno Reservoir. Povodí Vltavy, s.p. (J. Hejzlar)

2013 Research of separation of reservoir sediments – CREA Hydro Energy o.s. (J. Borovec)

Students' theses finished in 2013

Ph.D. **Monika Krolová:** Factors affecting the occurrence of littoral vegetation in a reservoir with storage function (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Hejzlar)

Ivana Vaníčková: The dynamics of sexual reproduction and ephippia production of Daphnia in reservoirs (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Seďa)

Michal Kratochvíl: Spatio-temporal distribution and feeding of age 0+ fish in different reservoir habitats (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Matěna)

Michal Tušer: Fish detection with modern sonar systems (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Kubečka and H. Balk)

Milan Muska: Spatial distribution of fish in reservoirs and lakes (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Kubečka)

Mgr. (Ing.) (M.Sc.) **Iva Tomková:** Photochemical transformation of organic fixed nitrogen in natural waters (Faculty of Agriculture, University of South Bohemia, České Budějovice, supervised by P. Porcal)

Lukáš Vejřík: The use of artificial spawning substrates in order to understand the factors influencing the spawning site selection, depth of egg strands deposition and hatching time of perch (Perca fluviatilis L.) (Faculty of Science, University of South Bohemia, České Budějovice, supervised by M. Čech)

Marie Krausová: The relation of metabolism of nitrogen and cation exchange capacity in acidifies soils of Šumava mountains (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Kaňa)

Michaela Holubová: Species composition and size of fish schools in open water habitat of canyon-shaped reservoir (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Peterka)

Jiří Richta: A comparison of the visual classic method for monitoring ichthyofauna of newly created post-minig lake Milada (hydric reclaimed opencast mine Chabařovice) (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Peterka)

Marek Šmejkal: The importance of various types of littoral habitats for fish in reservoirs (Faculty of Science, University of South Bohemia, České Budějovice, supervised by M. Prchalová)

Bc. (B.A.) **Anna Lachmanová:** Diet of selected fish species according to their ontogenetical state and environmental factors (Faculty of Science, University of South Bohemia, České Budějovice, supervised by J. Kubečka and M. Říha)

Tomáš Dvořák: Size selectivity of common European fish captured by gillnets (Faculty of Science, University of South Bohemia, České Budějovice, supervised by M. Prchalová)

Publications

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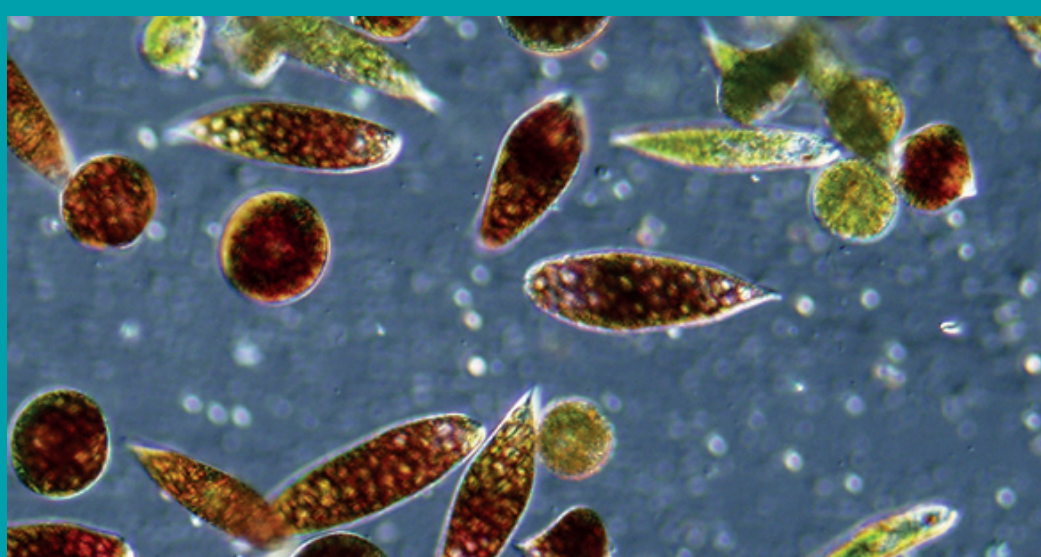

Zeleně a červeně zbarvené buňky krásnoočeček (Euglena sp.). / Green and red coloured cells of euglenophytes (Euglena sp.). / Foto P. Znachor.