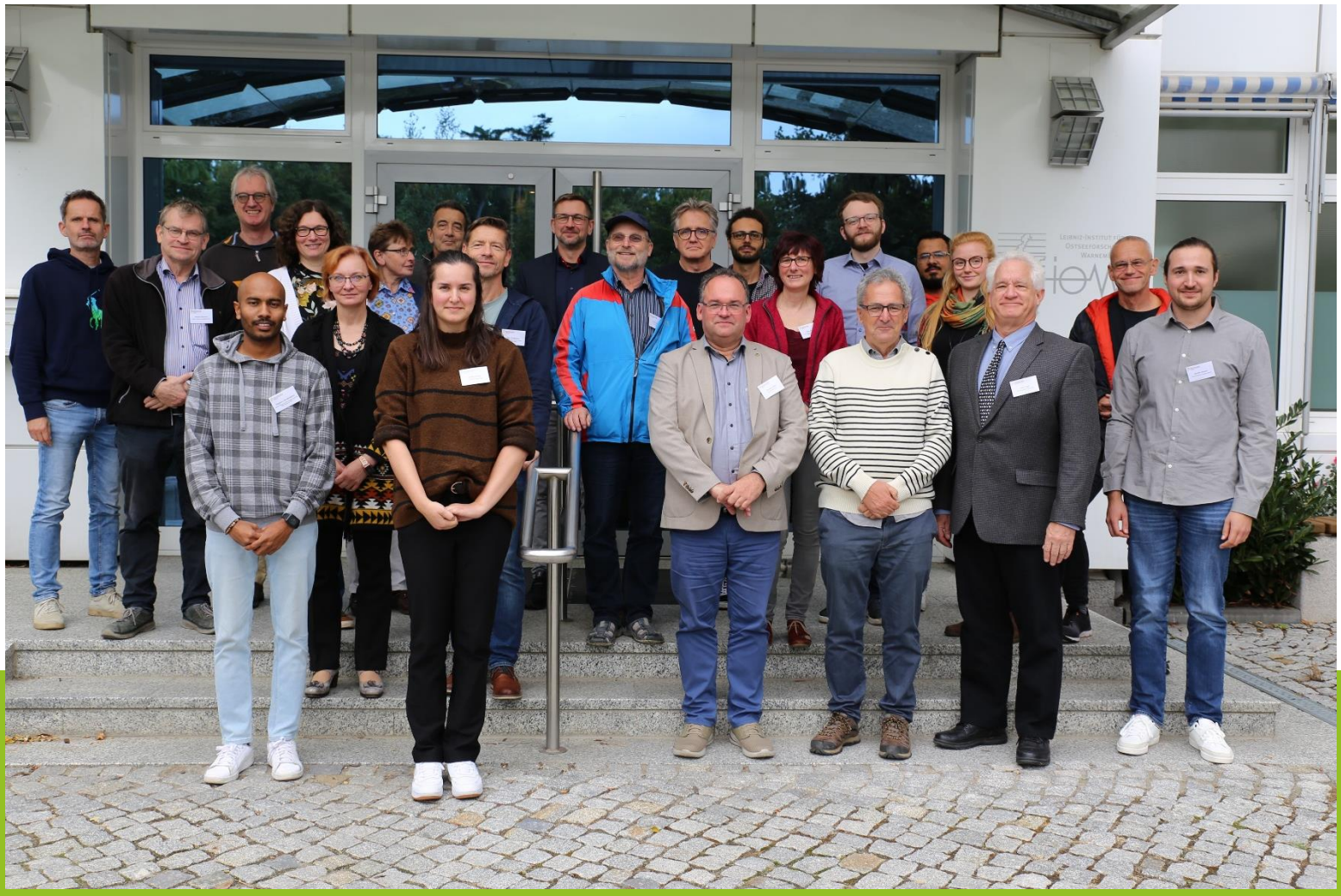
LEIBNIZ SCIENCE CAMPUS
PHOSPHORUS RESEARCH
ROSTOCK



Activity Report 2023

LIKAT Leibniz-Institut für Katalyse e.V. · INP FROM IDEA TO PROTOTYPE · Leibniz Institute for Baltic Sea Research Warnemünde (IOW) · IPK Leibniz Institute · FBN Research Institute for Farm Animal Biology · Universität Rostock Traditio et Innovatio

Content

1 Development of the Leibniz ScienceCampus Phosphorus Research Rostock (Introduction)

The Leibniz ScienceCampus Phosphorus Research Rostock (P-Campus) is linking the phosphorus research of currently (December 2023) 90 scientists from six research institutes in different disciplines working in 18 third-party funded projects (including PGS2). It focuses on three main areas in the support of phosphorus research by its members: strengthening of **networking**, **internationalization** and funding of **graduate students**.

Events of various formats were held in 2023 by the P-Campus to promote **networking** at all levels. Internal meetings and workshops serve the intensive networking of the scientists of the P-Campus and the further thematic development. Special events for the PhD students in the P-Campus within the framework of the **P-Campus Graduate School** (PGS), such as the lecture series and the annual symposium, serve in particular to promote networking and professional exchange among PhD students. Further details can be found in chapter 3.3 P-Campus Graduate School.

As an event for **internationalization** for all members of the P-Campus (and external interested parties), the **International P-Campus Symposium** with participation of the International Advisory Council of the P-Campus can be highlighted. The symposium was held as a hybrid event on October 9-10, 2023 with more than 40 participants.

Furthermore, the P-Campus is an active member of the **German Phosphorus Platform** (DPP) and the **European Sustainable Phosphorus Platform** (ESPP). Further networking activities are e.g. the integration of further PhD students of partner institutes with topics in the field of phosphorus research from various sources of funding. In addition, members of the P-Campus are internationally active throughout the year. The P-Campus contributes to the financial support of young scientists in their **international activities** and co-finances the participation in conferences and research stays. As most PhD students were about to complete their project or dissertation in 2023, only a few trips were made.

In spring 2020, a student taster day was to be held at the University of Rostock for pupils in year 11. Unfortunately, this on-site event had to be cancelled due to coronavirus restrictions. The student taster day then took place on July 11, 2023. Further details can be found in chapter 5 Events.

The **Graduate School Phosphorus Research** is the core of the graduate concept of the P-Campus and has the overarching goal of an excellent graduate education. Thematic training and the lively exchange of information among PhD students are supported by different events (thematic workshops, professional training, informal meetings etc.). Moreover, a lecture series was again organized in 2023 (Table 6).

By October 2022, seven PhD theses from PGS1 had been successfully defended. In 2023, an eighth PGS1 doctoral thesis was still in progress and about to be submitted. By December 2023, four doctoral theses from the 15 funded PhD projects in PGS2 had been successfully defended. A fifth was submitted and will be defended at the beginning of January 2024.

To continue the successful concept of the **seed projects**, the first six seed projects were already granted as of June 2019 and completed by 2022, meaning that the final reports

for these projects are also available in full (Table 2). In 2022, two calls for seed projects with regard to the continuation of the P-Campus after 2023 were initiated by the P-Campus. A total of eleven seed projects were approved in 2022 (Table 2). One was completed in 2022; the others were still running in 2023.

The **public relations work** of the P-Campus included, besides text writing, publishing and presentations, also the maintenance of the website. The "Long Night of the Sciences" took place in 2023. A number of P-Campus members took part and presented their research to the public.

The P-Campus will run until March 31, 2024, including another cost-neutral extension. **Continued funding of the P-Campus after 2023** is currently being worked out under the organization of the coordination office. Two funding lines are being pursued, on the one hand the organization of a Leibniz Research Alliance and on the other hand a DFG Research Training Group.

Leibniz Research Alliances are alliances between thematically focused, nationwide collaborating Leibniz institutes and universities in which joint doctorates are sought. Funding is provided for a maximum of three times four years; in addition to the Leibniz Association's funding, the participating institutes must also contribute their own funds. **The Leibniz Research Network "P Health – Phosphorus in Agriculture, Environment and Nutrition: Ecological Consequences and Societal Challenges"** (working title) is to consist of four main research areas (I. P in Agriculture and Nutrition, II. P in the Environment, III. P Recycling, IV. P-Resources, P-Governance) and a cross-sectional topic (Transfer and Education).

A DFG Research Training Group is designed to promote young researchers and, in addition to a research program at a high scientific level, also includes a study program with innovative teaching and supervision elements. The maximum funding period is two times four and a half years. The envisaged **DFG Research Training Group "PhAMoS - Phosphorus Acquisition, Metabolism and Signaling in aquatic and terrestrial organisms"** now contains two overarching themes ("T1 Interactions between organisms/cells and the environment: regulatory mechanisms of P uptake, storage and release" and "T2 Role of biological P forms in the coordination of signaling pathways and metabolic cycles in the cell"). Six subprojects can be assigned to topic T1, three subprojects to topic T2, and another three subprojects can be assigned to both topics.

Both funding lines are developed with delimited but complementary research questions, so that collaborations between the projects and researchers (mainly PhD students) are possible. In addition to funding research and graduate training in the P-Campus, both funding lines also maintain the interdisciplinary networking of the P-Campus members and at the same time extend the network to other (Leibniz) institutes and thus also new partners.

2 Goals and Concept

The overarching goal of interdisciplinary cooperation at the Leibniz ScienceCampus Phosphorus Research Rostock is, through a thematically oriented integrated network, to explore options for the more sustainable management of phosphorus. Further focuses of the P-Campus, in addition to the sufficient and efficient use and recycling and recovery of phosphorus, are phosphorus cycles and fluxes in the environment and the environmental problems, in particular in aquatic systems, caused by inefficient phosphorus use or a lack

of phosphorus recycling. Research is also conducted on the catalysis and synthesis of phosphorus-containing organocatalysts in chemical processes and medicine.

Expertise in various aspects of research into the essential and irreplaceable element phosphorus, diverse phosphorus-containing chemical compounds, and specific modes of action of phosphorus in agricultural and environmental systems as well as in technical and industrial processes are brought together at the P-Campus. In addition to fundamental and applied research, the aim is to contribute to economic development through the simultaneous development and transfer of technologies. Moreover, cooperation and research are intensified, and strong national and international networks are being established.

The following institutes are partners of the P-Campus:

- Leibniz Institute for Catalysis (LIKAT) at the University of Rostock
- Leibniz Institute for Baltic Sea Research (IOW), Warnemünde
- Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Satellite Collections North, Groß Lüsewitz
- Leibniz Institute for Plasma Science and Technology (INP), Greifswald
- Research Institute for Farm Animal Biology (FBN), Dummerstorf
- University of Rostock (Faculty of Agricultural and Environmental Sciences, Interdisciplinary Faculty, Faculty of Law, Faculty of Mathematics and Natural Sciences, Rostock University Medical Centre)

3 Research

3.1 Research Foci

The research foci of the P-Campus are:

- Cluster I: P in the Environment
- Cluster II: Sufficiency and Efficiency of P Utilization, P Recycling
- Cluster III: P in Synthesis and Catalysis
- Cluster IV: Molecular Biology of P
- Cluster V (cross-topic): P Governance

Table 3a (for PGS 1) and 3b (for PGS 2) list the exact research topics in each research cluster. It should be noted that in the following listings, some publications may be assigned to more than one research cluster.

3.1.1 Cluster I: P in the Environment

Phosphorus ends up in the environment through open-ended industrial cycles and along river flows, reaching the sea. The aim is a better understanding of P fluxes and cycles in the environment in order, on the one hand, to analyze the effects of high P inputs and, on the other, to enable discussion of protection and/or rehabilitation measures. This starts at the "sources", for example with the application of fertilizer on agricultural land and the effects of artificial drainage (drain systems), but also at the river outlets of small and large wastewater treatment plants. And it continues through phosphorus fluxes in different ecosystems, from special soil crusts to coastal waters and into the large Baltic Sea basin. Methodological approaches in Cluster I include measurements on the smallest

scale up to the Baltic Sea ecosystem modellings over a wide range of scales and instrumentation. Within the graduate school, research is being conducted on coastal wetland rewetting, P pools and their mobilization in coastal soils and sediments, and glyphosate and its degradation products in seawater.

In "Cluster I: P in the environment", eighteen publications were published. For 2023, the two publications by PhD student J. Prüter in project I.2 P-Pools should be highlighted in particular, as they demonstrate how complementary advanced analytics (NMR and synchrotron-based spectroscopy) can be used to gain new insights into the transfer and conversion of differently stable inorganic and organic P compounds. The experiments and investigations for both projects required the PhD student to familiarize herself with a high degree of new analytical methods at cooperating research institutions abroad, which fulfilled the Leibniz Campus's requirement for very thorough support of PhD students in a special way.

Prüter, J., McLaren, T.I., Pätzig, M., Hu, Y., Leinweber, P. (2023) Phosphorus speciation along a soil to kettle hole transect: sequential P fractionation, P XANES, and ^{31}P NMR spectroscopy. Geoderma 429, 116215 DOI: 10.1016/j.geoderma.2022.116215

Prüter, J., Schumann, R., Klysubun, W., Leinweber, P. (2023) Characterization of phosphate compounds along a catena from arable and wetland soil to sediments in a Baltic Sea lagoon. Soil Syst. 2023, 7, 15, DOI: 10.3390/soilsystems7010015

3.1.2 Cluster II: Sufficiency and Efficiency of P Utilization, P Recycling

The goal is to formulate a scientific basis with which to derive the necessary legal framework and policy recommendations for the sustainable management of regional and global closed P-fluxes in accordance with the principles of sufficiency and efficiency (see also Cluster V. P-Governance). Sufficiency means to limit the application rates of P for the production of plant and animal foods to the level actually required. This requires critical evaluations of existing P-fertilization and feed recommendations with the aim of reducing P-use in agriculture. The following research topics are elaborated in the second funding period within the framework of PhD projects in PGS 2: P recycling in animal husbandry, efficiency of recovered phosphorus for monogastric animals and P efficiency of forage legumes. The economic efficiency of the processes will also be investigated. Research in Cluster II thus covers all sub-areas of the agricultural P cycle (soil, plant, animal, water, process engineering, ...).

In 2023, 13 publications were published in "Cluster II: Sufficiency and Efficiency of P Utilization, P Recycling". The following publications are particularly highlighted as they deal with the use of insects as an alternative source of food and the upcycling of waste material with a view to future food security:

Seyedalmoosavi, M. M., Dannenberger, D., Pfuhl, R., Görs, S., Mielenz, M., Maak, S., Wolf, P., Daş, G., & Metges, C. C. (2023) Lipid metabolism, fatty acid composition and meat quality in broilers supplemented with increasing levels of defrosted black soldier fly larvae. Journal of Insects as Food and Feed 9(5), 583-598, DOI: 10.3920/JIFF2022.0125

Seyedalmoosavi, M. M., Mielenz, M., Schleifer, K., Görs, S., Wolf, P., Tränckner, J., Hüther, L., Dänicke, S., Daş, G., Metges, C.C. (2023) Upcycling of recycled minerals from sewage sludge through black soldier fly larvae (*Hermetia illucens*): impact on growth and mineral accumulation. Journal of Environmental Management 344, 1-12, DOI: 10.1016/j.jenvman.2023.118695

3.1.3 Cluster III: P in Synthesis and Catalysis

Cluster III is concerned with research into fundamental questions relating to the structure and reactivity of phosphorus-containing compounds. Due to the extraordinary variability of phosphorus with respect to its oxidation states (-3 to +5) and coordination numbers, phosphorus-containing compounds of various structures and properties are known. They are used in almost all areas of chemistry. In organometallic and coordination chemistry, phosphorus-containing compounds play a central role as ligands, for example in transition metal complexes. Both in research and in industry, many of these complexes find application in catalysis. These complexes give access to numerous products and enable reactions in the first place. In terms of sustainable chemistry, these catalysts make a major contribution to the development of energy and resource-efficient processes.

Phosphorus-containing compounds also play a central role as organocatalysts and, above all, as reagents in organic synthesis. Without them, the production of natural substances and new pharmacological agents, e.g. in medicinal chemistry, would often not be possible. Even today, we encounter products containing the element phosphorus in many areas of daily life, such as plant protection agents, flame retardants and light-emitting diodes.

In PGS 2, issues related to the synthesis of P-based ligands, the application of P-based organocatalysts, the synthesis of antitumor compounds and P-based methods for the activation of N-H bonds are addressed.

In 2023, twelve publications were published in "Cluster III: P in Synthesis and Catalysis". The following publications should be highlighted here in particular, as they represent a significant contribution to P chemistry and catalysis:

Siewert, J.-E., Puerta Lombardi, B. M., Jannsen, N., Roesler, R., Hering-Junghans, C. (2023) Synthesis and ligand properties of chelating bis(N-heterocyclic carbene)-stabilized bis(phosphinidenes). Inorg. Chem. 62, DOI: 10.1021/acs.inorgchem.3c02264

Ren, C., Terazzi, C., Werner, T. (2023) Tuneable reduction of CO_2 – organocatalyzed selective formylation and methylation of amines. Green Chem. 2024, 26 (1), 439-447, DOI: 10.1039/D3GC03993E

Tönjes, J., Kell, L., Werner, T. (2023) Organocatalytic stereospecific Appel Reaction. Org. Lett. 2023, 25 (51), 9114-9118, DOI: 10.1021/acs.orglett.3c03463

3.1.4 Cluster IV: Molecular Biology of P

The overarching goal is to unravel the central role of P as a metabolic, signaling and regulatory molecule from molecular to ecosystem levels. In fact, P acquisition, mobilization and assimilation involve various molecular mechanisms in microorganisms, plants and animals. Moreover, P plays a key role in signaling at the level of ecosystems, organisms and cells. Projects in this cluster aim to analyze the molecular mechanisms related to the uptake of P from the environment into the organism, the distribution, storage and mobilization of P within the organisms and its essential roles in the cellular metabolism as well as in the crosstalk of microorganisms, cells and tissues.
The PhD students of PGS 2 are working on the following topics: Gene expression in biological soil crusts, candidate genes for P production in potatoes, phosphate availability and the development of cyanobacterial blooms in the Baltic Sea, P during environmental stress in mollusks like mussels, and molecular mechanisms of P homoeostasis in birds (domestic chicken) and mammals (domestic pig).

In 2023, eleven publications could be assigned to "Cluster IV: Molecular Biology of P". The highlighted publications in Cluster IV deserve attention as they address the molecular and cellular mechanisms related to phosphorus metabolism in both domesticated (pigs) and wild (oysters) organisms. The following manuscripts, authored by PhD students as first authors, have already been significantly cited by the end of 2023, with 14 citations for Adzigbli et al. (2022) and 4 citations for Hasan et al. (2022), highlighting their impact on their respective research areas. These studies involve collaborations between Leibniz and university partners, and both articles are available in open access.:

Adzigbli, L., Sokolov, E. P., Ponsuksili, S., Sokolova, I. M. (2022) Tissue- and substrate-dependent mitochondrial responses to acute hypoxia–reoxygenation stress in a marine bivalve (*Crassostrea gigas*). J Exp Biol 225 (1), DOI: 10.1242/jeb.243304

Hasan, M., Oster, M., Reyer, H., Ponsuksili, S., Murani, E., Wolf, P., Fischer, D.-C., Wimmers, K. (2022) Tissue-Wide Expression of Genes Related to Vitamin D Metabolism and FGF23 Signaling following Variable Phosphorus Intake in Pigs. Metabolites 12, 729, DOI: 10.3390/metabo12080729

For 2023, the following publications are also highlighted in Cluster IV, as they shed light on the molecular pathways of vitamin D-dependent regulation of P homeostasis and its exogenous modulation:

Hasan, M., Reyer, H., Oster, M, Trakooljul, N., Ponsuksilli, S., Magowan, E., Fischer, D.-C., Wimmers, K. (2024) Exposure to artificial ultraviolet-B light mediates alterations on the hepatic transcriptome and vitamin D metabolism in pigs. The Journal of Steroid Biochemistry and Molecular Biology 106428, DOI: 10.1016/j.jsbmb.2023.106428

Hasan, M., Oster, M., Reyer, H., Wimmers, K., Fischer, D.C. (2023) Efficacy of dietary vitamin 3 and 25(OH)D3 on reproductive capacities, growth performance, immunity and bone development in pigs. British Journal of Nutrition 28;130(8):1298-1307, DOI: 10.1017/S0007114523000442

3.1.5 Cluster V (cross-topic): P Governance

Cluster V of the P-Campus aims at possible policy instruments to strengthen P-recycling (consistency), efficiency and sufficiency in the use of P-fertilizers and deals with their implementation in society and agricultural practice through effective legal frameworks. The aim of the subproject is to deepen the analysis and further development of agricultural, fertilizer, water, soil protection, waste and recycling legislation and to develop concrete governance options for closed P cycles at different legal levels. Natural scientific findings generated within the framework of the P-Campus will be included as well as current political and legal developments. A current priority is the monitoring and further development of the EU Common Agricultural Policy for the 2021-2027 funding phase. This topic (Governance options for closed P cycles - the CAP 2020 revision) is addressed in the context of PGS 2.

In Cluster V, seven publications were published in 2023. In particular, the following two publications can be highlighted:

1. Heyl, K., Döring, T., Garske, B., Stubenrauch, J., Ekardt, F.: The Common Agricultural Policy beyond 2020: A critical review in light of global environmental goals, in: Review of European, Comparative & International Environmental Law (2021) 30(1).

The article provides a comprehensive overview of the reform proposal for the future Common Agricultural Policy and critically examines the extent to which the proposed measures are in line with legally binding environmental objectives.

2. Heyl, K., Ekardt, F., Roos, P., Garske, B.: Achieving the nutrient reduction objective of the Farm to Fork Strategy. An assessment of CAP subsidies for precision fertilization and sustainable agricultural practices in Germany, in Frontiers in Sustainable Food Systems (2023) 7.

In the context of the ongoing digitalization of the agricultural sector, this article examines the extent to which the national implementation of EU agricultural subsidies in Germany promotes precision fertilization. In addition, measures to promote sustainable land management are critically examined.

3.2 Research Projects

Within the research clusters, 19 disciplinary and interdisciplinary, third-party funded projects (including PGS 2) were thematically assigned to the P-Campus in 2023 (Table 1). Two of these projects started newly in 2023 and four projects ended in 2023.

Table 1. Third-party funded research projects thematically assigned to the P-Campus (status as of December 2023; *in italics: phosphorus not a subject of the total project or members of the P-Campus only active in parts of the project*)

Project Name	Term	Sponsor	Participating Partners of the P-Campus	Cluster
Baclofen: Entwicklung effizienter Produktionsverfahren für die Darstellung von Baclofen und hiermit verwandter pharmazeutischer Produkte	*10/2020-09/2023*	*BMWi, AIF*	*University of Rostock (MNF)*	*IV*
Baltic Transcoast	*01/2016-12/2024*	*DFG*	*University of Rostock (AUF, MNF), IOW*	*I*
BioAdvan: Advanced Biomass-Treatment for Value-Added Refinement	03/2023-02/2026	WGL	INP, University of Rostock (AUF)	II
Crustfunction III – Landnutzung als Treiber der Struktur und Funktionalität biologischer Bodenkrusten	08/2020-12/2023	DFG	University of Rostock (AUF, MNF)	I
EU-Conexus Plus	*11/2022-10/2026*	*EU Commission*	*University of Rostock (AUF)*	
Graduate School II: Leibniz ScienceCampus Phosphorus Research Rostock	07/2019-11/2023	WGL	FBN, IOW, INP, IPK, LIKAT, University of Rostock	I, II, III, IV, V
HyGreen: Genom-basierte Strategien zur Züchtung von Hybridsorten bei Grünroggen als nachwachsender Rohstoff für die energetische Nutzung: TV 1: Genotypisierung und Phänotypisierung	12/2021-11/2024	FNR	University of Rostock (AUF)	
InFertRes: Innovative Fertilizers and Resource Efficiency in Agriculture	03/2018–04/2024	BMBF	University of Rostock (AUF)	II
InnoSoilPhos III: Innovative solutions to sustainable soil phosphorus management	05/2021 – 04/2024	BMBF	University of Rostock (AUF)	I, II, Q

Project Name	Term	Sponsor	Participating Partners of the P-Campus	Cluster
Innovationsraum: BaMS-RüBio - Blaue Bioökonomische Kreislaufwirtschaft für Rügen (TP 3) - Umsetzungsphase. "Welsaquaponik am Standort Bergen auf Rügen"	*01/2022-12/2024*	*BMBF*	*University of Rostock (AUF), FBN*	*II*
MikroMais: Verbundvorhaben: Reduzierung des Grundwasser-relevanten Stickstoff- und Phosphor-Überschusses durch kombinierte Mikrogranulat-Mikroorganismen- Ausbringung auf Gärrest-gedüngten Flächen im Energiemaisanbau; Teilvorhaben 2: Nährstoffverfügbarkeit und Nährstoffverlagerung im Boden	04/2021-03/2024	BMEL	University of Rostock (AUF)	II
MitoBOX: The mitochondrial basis of hypoxia tolerance in marine mollusks	*04/2019-09/2023*	*DFG*	*University of Rostock (MNF)*	*IV*
P-FOWL: Characterization of mineral utilisation by functional genomics in two contrasting high-yielding laying hen strains	09/2022-08/2025	DFG	FBN	IV
P-FOWL: Epigenetics, molecular pathways, and data integration to derive biological networks related to myo-inositol and P utilization in two contrasting high-yielding laying hen strains	10/2022-09/2025	DFG	FBN	IV
**PROCESSOR: Phosphorus recycling from complex scarcely soluble societal resources – letting the soil do the work*	*2021-2024*		*University of Rostock (AUF)*	*II*
UVISION: Erforschung des Potenzials von Sekundärmetaboliten aus marinen Ressourcen für den UV-Schutz des menschlichen Auges	01/2023-12/2025	DFG, FWF	LIKAT, University of Rostock (MNF)	II, IV
Verbundvorhaben: Erhöhung der Anbauwürdigkeit von Luzerne (Medicago sativa L.) als Futterpflanze - Neue Impulse für die Königin der Futterpflanzen	*04/2021-04/2024*	*BMEL*	*IPK*	*II*
Verbundvorhaben: Selektion und Züchtung nährstoffeffizienter, Phytophthora-resistenter Kartoffelzuchtstämmen für einen nachhaltigen ökologischen Landbau	*03/2020-02/2024*	*BMEL*	*IPK*	*II*
VitD-Pig: Functional signals for vitamin D-mediated mineral utilization and related physiological determinants in pigs	11/2022-10/2025	DFG	FBN	IV

* Project PROCESSOR: A project of the associated partner WG Soil Fertility (Prof. J. Magid) at the University of Copenhagen; Prof. P. Leinweber (University of Rostock, WG Soil Science) and Prof. E. Frossard (ETH Zurich, Professor of Plant Nutrition at the Institute of Agricultural Sciences, member SAC of the P-Campus) function as co-supervisors for chemical analysis, e.g. isotope, XANES and NMR analyses.

The Graduate School 1 (**PGS 1**) consisted of eleven sub-projects (Table 3a in chapter 3.3). Two projects were discontinued for personal reasons by the PhD students and the projects were finished by the supervisors. Seven dissertations were successfully completed by the end of October 2022. An eighth dissertation is being finalized and submission is planned for early 2024. The second P-Campus Graduate School (PGS 2) consists of 15 sub-projects (Table 3b in Chapter 3.3), all of which started by October 2020. Further details on the projects are presented in Chapter 3.3.

In order to continue the successful concept of the **seed projects**, the first six seed projects were approved in June 2019. The projects have all been completed, so that all the

respective short reports of the completed projects (green) can be made available on request. In May (deadline in August) and in September (deadline in October) 2022, two calls for seed projects were initiated by the coordination office of the P-Campus. The projects are to be aligned as preliminary work to the envisaged Leibniz Research Alliance "P-Health - Phosphorus in agriculture, food and environment: Ecological consequences and societal challenges" and the DFG Research Training Group "PhAMoS - Phosphorus acquisition, metabolism and signaling in aquatic and terrestrial organisms". Six projects were submitted and approved for the summer call and five for the fall call. As usual, all seed projects are designed as collaborative projects between at least two partners. One project was completed in 2022, all others in the course of 2023 and some in early 2024.

Table 2. Seed projects of the P-Campus 2019-2023, funded by WGL grant of the P-Campus (finished projects with final report available in green, projects for which the final report is expected in 2024 in orange)

Project	Participating Partners
Funding period 2, call for proposals 1 (2019)	
Phosphor - Protein - Interaktionen in der Quervernetzung (P-ChemBind)	LIKAT, UR
Phosphorus as a cue regulating microbial N_2O production (PQ4N)	UR, IOW
Plasmainduzierte Abbaureaktionen in Glyphosat-haltigen Substraten (PIAG)	UR, INP
Die Rolle von Protisten im Phosphorkreislauf biologischer Bodenkrusten (ProCycle)	UR, IOW
Dietary effects on DNA methylation in porcine parathyroid glands (EpiPTG)	FBN, UR, UMR
Entwicklung enantioselektiver katalytischer Wittig Reaktionen basierend auf chiralen Phosphorverbindungen als Katalysatoren (P-CAT)	UR, LIKAT
Funding period 2, call for proposals 2 (August 2022)	
2022-01 Recht und Governance der Gewässer – international, europäisch, national (Governance-Wasser)	UR/FNK, IOW
2022-02 Die neuen Phosphor-Bodenfertilitätsklassen und ihre Beziehungen zu Phytodiversität und Vegetationstypen (PhosPhyDiv)	UR: LÖ, Grünland
2022-03 Methodische Voruntersuchungen für die Analytik von MPn (MPn-Analytik)	IOW, UR
2022-04 Plasmaunterstützte Behandlung von Biomasse und Klärschlämmen für die Phosphorrückgewinnung (PlaBiPhos)	INP, UR
2022-05 Development of an ELISA for quantification of FGF23 as a marker of phosphate homeostasis in pigs (porcine FGF23, ELISA))	FBN, UMR
2022-06 Gennetzwerke des Phosphormetabolismus von Fischen und fakultativ anaeroben Invertebraten (GePFI)	FBN, UR
Funding period 2, call for proposals 3 (October 2022)	
2022-07 Plasmaunterstützte Oxidation von Phosphonsäureabfällen für die Phosphorrückgewinnung (Plasma)	INP, UR
2022-08 Erfassung der Kulturpflanzen-Wurzelarchitektur in Medium Size-Rhizotronen (MedRhizo)	INP, UR
2022-09 Root exudations and root architecture in mixed crops (MixedRoots)	UR, INP
2022-10 Untersuchung ausgewählter Antikörper für die immunhistochemische Analyse der Nebenschilddrüsen von Schweinen (histoNSD)	UMR, FBN
2022-11 Cultivation of bone-forming cells and analysis of respective expression profiles (CULTIVATE)	FBN, UMR

Abbreviations: FBN= Research Institute for Farm Animal Biology, FNK = Research Unit Sustainability and Climate Policy, INP = Leibniz Institute for Plasma Research and Technology, IOW = Leibniz Institute for Baltic Sea Research Warnemünde, LIKAT = Leibniz Institute for Catalysis, UMR = Rostock University Medical Center, UR = University of Rostock

3.3 Graduate School Phosphorus Research

The structured training concept of the P-Campus (see Figure 1) is realized by graduate studies at the Graduate School of Phosphorus Research and the involvement of other young scientists (BSc and MSc students, PhD students, and postdocs) whose thesis or project concerns phosphorus research. Special events, inclusion in the information and notification mailing lists, participation in P-Campus events, financial support for internationalisation (travel, publications and guest researchers/stays) and active participation in scientific and thematic networks (e.g. DPP, ESPP) are offered.

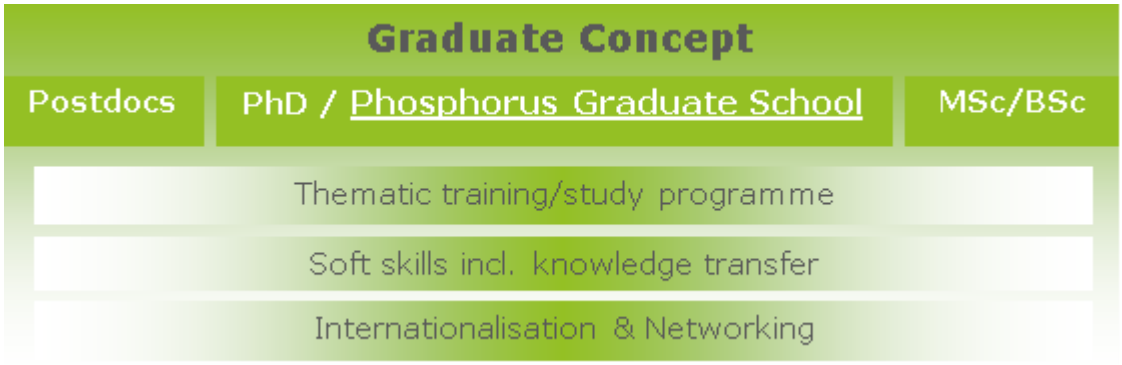


Figure 1. Graduate Concept of the Leibniz ScienceCampus Phosphorus Research Rostock

The Graduate School of Phosphorus Research is the core of the graduate concept of the P-Campus. Its overall objective is to provide excellent graduate education, to encourage new and innovative phosphorus research topics, and to foster networking among partners. The 11 PhD projects of the first period and the 15 PhD projects of the second period cover important areas of knowledge and research (Table 3a + 3b).

All PhD students are supervised by a committee of scientists from at least two partner organizations of the P-Campus. The students present their work at the annual P-Campus Symposium in autumn. Lively exchanges of information between PhD students are promoted through various events, such as workshops and the symposia. Positive support for these activities has come from opening the events to other PhD students with thesis topics in phosphorus-related research.

For 2023, a **lecture series** with eight lectures on the element P was also organized by the P-Campus coordination office. The lecture series also serves the interdisciplinary knowledge transfer of the PhD students. Six scientists from outside the P-Campus presented their research on the element P at the lecture series in 2023. (Table 6 in chapter 5 Events).

At the **P-Campus Symposium** on October 9-10, 2023, 13 PhD students presented their work in the form of talks (10) or posters (3) (Table 5 in chapter 5).

By the end of 2022, seven PhD students of the first graduate school (PGS1) had successfully completed their dissertation. An eighth dissertation is to be submitted at the beginning of 2024. The successfully defended dissertations are listed in green font in table 3a. Thus, of the original eleven projects, only two dissertations were cancelled for personal reasons and the projects were completed by the supervisors (marked in red). One project was completed by the PhD student, however, the submission of the dissertation is no longer planned.

Table 3a. Subprojects of the Graduate School 1 (PGS 1; 2015-2019, financed by the Leibniz Association) (green: project and dissertation fully completed, orange: project completed and dissertation still planned, red: dissertation discontinued, project terminated by supervisor; blue: Project completed by PhD student, but dissertation no longer planned)

Project	Participating Partners	Research Focus
Quality, quantity and transformation of P losses from diffuse sources to the Baltic Sea	IOW, UR	I
Phosphatases – Development of new quantitative assays along terrestrial-aquatic gradients	UR, IOW	I
Natural and anthropogenic organic P compounds – inositol-phosphates, phospholipids and glyphosate	IOW, UR	I, II, Q
Mechanisms of P mobilization in the rhizosphere involving weeds and crop plants	UR, IPK	II
Genetic regulation of phosphatase production and activity to increase P uptake from deficient soils	UR, IPK	II
Genetic and nutritional effects on the efficiency of P use of monogastric animals	FBN, UR	II
The P cycle and its application in land-based integrated aquaculture systems	UR, FBN	II
Political-legal P governance by means of certificate markets and charges	UR, IOW	II
Processing of alternative P sources for fertilization in agriculture	INP, UR	II, III
Synthesis of new heterocyclic ring systems containing P	LIKAT, UR	III
Large scale application of P based organocatalysts in batch and flow for the synthesis of fatty acid derived cyclic carbonates	LIKAT, UR	III

In PGS 2, all 15 PhD projects started by November 2020. Since some PhD students did not start until third or fourth quarter 2020 (delays due to Corona restrictions), PGS 2 was extended cost-neutrally for the first time until November 30, 2023 (originally May 31, 2023). In the last quarter of 2023, a further cost-neutral extension was granted until March 31, 2024 in order to support PhD students for their (cumulative) dissertation with the remaining funds.
The PhD students presented their results at (international) conferences with posters or talks (see chapter 6). Despite remaining restrictions, some PhD students had the opportunity to co-supervise students for their term papers or final theses (BSc, MSc) in 2023 and were thus able to gain valuable teaching experience. The publications highlighted in purple below received the P-Campus Publication Award.
Five dissertations were successfully defended by December 31, 2023; another one was submitted and successfully defended in January 2024. No dissertation is planned for two projects; submission is planned for all others in 2024.

The **project I.1 Risks and benefits of rewetting coastal wetlands after agricultural use (P-Risk)** had to be partly redesigned with regard to the project objectives, as the author passed away in May 2020. With 13 months remaining, Dr. Sate Ahmad conducted work on the risk of phosphorus discharge from coastal sites in accordance with the original objectives. Essentially, he has developed an estimation method to quantify phosphorus and nutrient discharge risk based on land use and groundwater levels along the coast. In addition, he has dealt with the renaturation of coastal wetland sites, looking at different ecosystems (literature study). A draft manuscript is available for each of the two areas of work (as of November 2022). In addition, a comprehensive final report on the project was submitted in November 2022. As the researcher has accepted a research

position outside Germany and is therefore no longer on site, it is not expected that the manuscripts will be published at short notice.

The **project I.2 P Pools and mobilization potential in lowlands and coastal regions (P-Pools)** ended in September 2022 after an extension of funding by the P-Campus. In that month, the PhD student (J. Prüter) also submitted the dissertation; the successfully defense was on January 25, 2023. J. Prüter is the lead author of the following publications:

Prüter, J., McLaren, T.I., Pätzig, M., Hu, Y., Leinweber, P. (2023) Phosphorus speciation along a soil to kettle hole transect: sequential P fractionation, P XANES, and ^{31}P NMR spectroscopy. Geoderma 429, 116215 DOI: 10.1016/j.geoderma.2022.116215

Prüter, J., Schumann, R., Klysubun, W., Leinweber, P. (2023) Characterization of phosphate compounds along a catena from arable and wetland soil to sediments in a Baltic Sea lagoon. Soil Syst. 2023, 7, 15, DOI: 10.3390/soilsystems7010015

Prüter, J., Hu, Y., Leinweber, P. (2022) Influence of sample pretreatment on P speciation in sediments evaluated with sequential fractionation and P *K*-edge XANES spectroscopy. Communications in Soil Science and Plant Analysis 53, 1712-1730, DOI: 10.1080/00103624.2022.2063317

Prüter, J., Strauch, S.M., Wenzel, L.C., Klysubun, W., Palm, H.W., Leinweber, P. (2020) Organic matter composition and phosphorus speciation of solid waste from an African Catfish recirculating aquaculture system. Agriculture MDPI 10, 466; DOI: 10.3390/agriculture10100466 (open access)

Prüter, J., Leipe, T., Michalik, D., Klysubun, W., Leinweber, P. (2019) Phosphorus speciation in sediments from the Baltic Sea, evaluated by a multi-method approach. Journal of Soils and Sediments, DOI: 10.1007/s11368-019-02518-w

The **project I.3 Analysis of glyphosate and glufosinate in sea water and as indicator compounds for industrial cropping (Glyphosate)** started in January 2020 with a PhD student who was already working with another funding since October 2017 on the topic of detection of glyphosate and similar compounds in sea water. She was able to successfully contribute her previous experience and results to the project and defended her dissertation in the summer of 2021. In 2022, further work on the development of a method for the determination of particulate glyphosate was carried out as part of a research internship. M. Wirth is lead or co-author of the following publications:

Wirth, M.A., Longwitz, L., Kanwischer, M., Gros, P., Leinweber, P., Werner, T. (2021) AMPA-^{15}N – Synthesis and application as standard compound in traceable degradation studies of glyphosate. Ecotoxicology and Environmental Safety 225, 1-8, DOI: 10.1016/j.ecoenv.2021.112768

Wirth, M.A., Schulz-Bull, D.E., Kanwischer, M. (2021) The challenge of detecting the herbicide glyphosate and its metabolite AMPA in seawater - Method development and application in the Baltic Sea. Chemosphere 262 (2021) 128327, DOI: 10.1016/j.chemosphere.2020.128327

Gros, P., Meissner, R., **Wirth, M.A.**, Kanwischer, M., Rupp, H., Schulz-Bull, D.E., Leinweber, P. (2020) Leaching and degradation of 13C2-15N-glyphosate in field. Environ Monit Assess 192: 127, DOI: 10.1007/s10661-019-8045-4

Lohrer, C., Cwierz, P., **Wirth, M.A.**, Schulz-Bull, D., Kanwischer, M. (2020) Methodological aspects of methylphosphonic acid analysis: Determination in river and coastal water samples. Talanta, DOI: 10.1016/j.talanta.2020.120724

Wirth, M.A., Sievers, M., Habedank, F., Kragl, U., Schulz-Bull, D.E., Kanwischer, M. (2019) Electrodialysis as a sample processing tool for bulk organic matter and target pollutant analysis of seawater. Marine Chemistry 217, DOI: 10.1016/j.marchem.2019.103719

The **project II.1 P recycling in animal husbandry (P-Recycling)** started in October 2019. The PhD student terminated the contract in fall 2021 due to another job opportunity. A new project worker was hired in January 2022 who completed the work in the project by September 2022. Due to the short processing time, a doctorate on this topic is not possible for the second processor. Two manuscripts emerged from the work in the project. After preliminary rejection of one manuscript, both articles were revised. The manuscript Schleyken et al. (2023) has already been published. The second one will be further revised and shall be submitted later.

Schleyken, J., Gumpert, F., Tränckner, S., Palm, H., Tränckner, J. (2023) Enhanced chemical recovery of phosphorus from residues of recirculating aquaculture systems (RAS). Int. J. Environ. Sci. Technol., 1-14, DOI: 10.1007/s13762-023-05226-8

The project **II.2 Efficiency of recovered phosphorus for monogastric animals (Monogastric)** started in November 2019 and ended on December 31, 2022. The dissertation was submitted at the end of 2023 and successfully defended in January 12, 2024. The FBN extended the employment contract until 28.02.2023 to allow the PhD student to complete and submit the dissertation. The PhD student is the lead author of the following publications:

Seyedalmoosavi, M. M., Daş, G., Mielenz, M., Wolf, P., Metges, C.C. Recycled-mineral enriched whole black soldier fly larvae in broiler diets: growth performance, nutrient intakes, blood metabolites and bone characteristics. (in preparation)

Seyedalmoosavi, M. M., Dannenberger, D., Pfuhl, R., Görs, S., Mielenz, M., Maak, S., Wolf, P., Daş, G., & Metges, C. C. (2023) Lipid metabolism, fatty acid composition and meat quality in broilers supplemented with increasing levels of defrosted black soldier fly larvae. Journal of Insects as Food and Feed 9(5), 583-598, DOI: 10.3920/JIFF2022.0125

Seyedalmoosavi, M. M., Mielenz, M., Schleifer, K., Görs, S., Wolf, P., Tränckner, J., Hüther, L., Dänicke, S., Daş, G., Metges, C.C. (2023) Upcycling of recycled minerals from sewage sludge through black soldier fly larvae (*Hermetia illucens*): impact on growth and mineral accumulation. Journal of Environmental Management 344, 1-12, DOI: 10.1016/j.jenvman.2023.118695

Seyedalmoosavi, M. M., Mielenz, M., Görs, S., Wolf, P., Daş, G., & Metges, C. C. (2022) Effects of increasing levels of whole Black Soldier Fly (*Hermetia illucens*) larvae in broiler rations on acceptance, nutrient and energy intakes and utilization, and growth performance of broilers. Poultry Science 101, 12, 1-15, DOI: 10.1016/j.psj.2022.102202

Seyedalmoosavi, M.M., Mielenz, M., Veldkamp, T., Daş, G., Metges, C.C. (2022) Growth efficiency, intestinal biology, and nutrient utilization and requirements of black soldier fly (*Hermetia illucens*) larvae compared to monogastric livestock species: a review. Journal of Animal Science and Biotechnology 13, 1-20, DOI: 10.1186/s40104-022-00682-7

The **project II.3 P efficiency of forage legumes and their capacity to utilize P from recycled products (P-Legumes)** started in November 2019 and ended on July 31, 2023 after a Corona-related extension. The cumulative dissertation is to be submitted in the first quarter of 2024; a third publication will be submitted in February 2024. The PhD student Yue Hu is lead author respectively co-author of the following publications:

Hu, Y., Dehmer, K., Willner, E., Eichler-Löbermann, B. (2023) Specific and intraspecific P efficiency of small-grain legumes as affected by long-term P management. Agronomy 13, 900, DOI: 10.3390/agronomy13030900

Hu, Y., Jarisch, K.A., Kavka, M., Eichler-Löbermann, B. (2022) Fate of P from organic and inorganic fertilizers assessed by complementary approaches. Nutr Cycl Agroecosyst, DOI: 10.1007/s10705-022-10237-x

Eichler-Löbermann, B., Koal, P., **Hu, Y.**, Dehmer, K.J. (2022) Nachhaltiges und effizientes Phosphor-Management im Pflanzenbau. In: Kinder haften für ihre Eltern – Impulse aus dem Ökolandbau. KTBL-Tagung 2022, S. 94-109

The **project III.1 Synthesis of novel P-based ligands for complexes to activate small molecules (P-Cord)** started in October 2020 and ended after a cost-neutral extension in November 2023. For the PhD student Jan-Erik Siewert, who was employed in the project, the Kekulé fellowship was obtained in summer 2021. The WGL and LIKAT funds thus freed up were then used to hire an additional *project researcher*. The dissertation was submitted on August 21, 2023 and successfully defended on December 19, 2023. The following publications were published in the project (**PhD student**, *project researcher*):

Siewert, J.-E., Schumann, A., Wellnitz, T., *Dankert, F.*, Hering-Junghans, C. (2023) Triphosphiranes as phosphinidene-transfer agents – synthesis of regular and chelating NHC phosphinidene adducts (invited contribution, HOT Article Collection). Dalton Trans. 52, DOI: 10.1039/D3DT02690F

Siewert, J.-E., Puerta Lombardi, B. M., Jannsen, N., Roesler, R., Hering-Junghans, C. (2023) Synthesis and ligand properties of chelating bis(N-heterocyclic carbene)-stabilized bis(phosphinidenes). Inorg. Chem. 62, DOI: 10.1021/acs.inorgchem.3c02264

Nees, S., *Beer, H.*, Just, P., Teichmeier, L. M., Christoffer, L. E., Guljam, A., Kushik, Braunschweig, H., Hering-Junghans, C. (2023) On the Reactivity of Mes*P(PMe_3) towards Aluminum(I) Compounds – Evidence for the Intermediate Formation of Phosphaalumenes (invited contribution). ChemPlusChem, e202300078, DOI: 10.1002/cplu.202300078

Nees, S., Wellnitz, T., *Dankert, F.,* Härterich, M., Dotzauer, S., Feldt, M., Braunschweig, H., Hering-Junghans, C. (2023) On the Reactivity of Phosphaalumenes towards C−C Multiple Bonds. Angew. Chem. Int. Ed. 62, DOI: 10.1002/anie.202215838

Täufer, T., *Dankert, F.*, Michalik, D., Pospech, J., Bresien, J., Hering-Junghans, C. (2023) Photochemical formation and reversible base-induced cleavage of a phosphagallene. Chem. Sci. 14, 3018-3023, DOI: 10.1039/D2SC06292E

Dankert, F., Fischer, M., Hering-Junghans, C. (2022) Modulating the reactivity of phosphanylidenephosphoranes towards water with Lewis acids. Dalton Trans. 51, 11267-11276, DOI: 10.1039/D2DT01575G (preprint available: DOI: 10.26434/chemrxiv-2022-drdkg (working paper))

Dankert, F., Gupta, P., Wellnitz, T., Baumann, W., Hering-Junghans, C. (2022) Deoxygenation of chalcogen oxides EO2 (E = S, Se) with phospha-Wittig reagents. Dalton Trans., 51, 18642-18651, DOI: 10.1039/D2DT03703C

Dankert, F., Hering-Junghans, C. (2022) Heavier group 13/15 multiple bond systems: synthesis, structure and chemical bond activation. Chem. Commun. 2022, 58, 1242-1262, DOI: 10.1039/D1CC06518A

Dankert, F., **Siewert, J.-E.**, Gupta, P., Weigend, F., Hering-Junghans, C. (2022) Metal-free N-H Bond Activation by Phospha-Wittig Reagents. Angew. Chem. Int. Ed. 2022, 61, 1-6, DOI: 10.1002/anie.202207064 (PrePrint available: DOI: 10.26434/chemrxiv-2022-w5xvh (working paper))

Gupta, P., Täufer, T., **Siewert, J.-E.**, Reiß, F., Drexler, H.-J., Pospech, J., Beweries, T., Hering-Junghans, C. (2022) Synthesis, Coordination Chemistry, and Mechanistic Studies of P,N-Type Phosphaalkene-Based Rh(I) Complexes. Inorg. Chem. 2022, 61, 30, 11639–11650, DOI: 10.1021/acs.inorgchem.2c01158

Gupta, P., **Siewert, J.-E.**, Wellnitz, T., Fischer, M., Baumann, W., Beweries, T., Hering-Junghans, C. (2021) Reactivity of phospha-Wittig reagents towards NHCs and NHOs. Dalton Trans. 50, 1838-1844, DOI: 10.1039/D1DT00071C

Nees, S., Fantuzzi, F., Wellnitz, T., Fischer, M., **Siewert, J.-E.**, Goettel, J. T., Hofmann, A., Härterich, M., Braunschweig, H., Hering-Junghans, C. (2021) Cyclo-Dipnictadialanes. Angew. Chem. Int. Ed., 60, 24318–24325, DOI: 10.1002/anie.202111121

Siewert, J.-E., Schumann, A., Hering-Junghans, C. (2021) Phosphine-catalysed reductive coupling of Dihalophosphanes. Dalton Transactions 42, 15111-15117, DOI: 10.1039/D1DT03095G

Siewert, J.-E., Schumann, A., Fischer, M., Schmidt, C., Taeufer, T., Hering-Junghans, C. (2020) Terphenyl(bisamino)phosphines: electron-rich ligands for gold-catalysis. Dalton Trans. 49, 12354-12364, DOI: 10.1039/D0DT02435J

Schumann, A., Reiß, F., **Siewert, J.-E.**, Jiao, H., Rabeah, J., Krummenacher, I., Braunschweig, H., Hering-Junghans, C. (2019) A selective route to aryl-triphosphiranes and their titanocene-induced fragmentation. Chem. Sci. 10, 7859-7867, DOI: 10.1039/C9SC02322D

The **project III.2 Application of P-based organocatalysts and biocatalysts for the resolution of racemic carbonates (P-RaceCar)** started in February 2020 and lasted after an extension until April 2023. The submission of the dissertation is planned for the second quarter of 2024. The PhD student is the lead author of the following publications:

Ren, C., **Terazzi, C.**, Werner, T. (2024) Tuneable reduction of CO_2 – organocatalyzed selective formylation and methylation of amines. Green Chem. 26 (1), 439-447, doi:10.1039/D3GC03993E.

Terazzi, C., Spannenberg, A., von Langermann, J., Werner T. (2023) Chemoenzymatic synthesis of chiral building blocks based on the kinetic resolution of glycerol-derived cyclic carbonates. ChemCatChem 2023, 15, e202300917, DOI: 10.1002/cctc.202300917

Terazzi, C., Laatz, K., von Langermann, J., Werner, T. (2022) Synthesis of cyclic carbonates catalyzed by CaI_2–Et_3N and studies on their biocatalytic kinetic resolution. ACS Sustainable Chem. Eng. 10, 40, 13335–13342, DOI: 10.1021/acssuschemeng.2c03210

The **project III.3 Synthesis of potential anti-tumor and adhesion-promoting agents by P-based organocatalysis for oncology and biomedical engineering (P-Med)** started in January 2020 and ended on December 31, 2022. The submission of the dissertation is planned for the second quarter of 2024. The PhD student is lead or co-author of the following publications:

Tönjes, J., Kell, L., Werner, T. (2023) Organocatalytic stereospecific Appel Reaction. Org. Lett. 25 (51), 9114-9118, DOI: 10.1021/acs.orglett.3c03463.

Tönjes, J., Longwitz, L. and T. Werner (2021) Poly(methylhydrosiloxane) as a reductant in the catalytic base-free Wittig reaction. Green Chem. 23, 4852-4857. DOI: 10.1039/D1GC00953B

Liu, X., Longwitz, L., Spiegelberg, B., **Tönjes, J.**, Beweries, T., Werner, T. (2020) Erbium-catalyzed regioselective isomerization–cobalt-catalyzed transfer Hydrogenation sequence for the synthesis of Anti-Markovnikov Alcohols from epoxides under mild conditions. ACS Catal. 2020, 10, 13659–13667, DOI: 10.1021/acscatal.0c03294

The **project IV.1 Gene expression in biogeochemical cycling of phosphorus in biological soil crusts of sand dunes of the Baltic Sea (Soil Crust)** started in June 2019 and ended on September 30, 2022, after a Corona-related extension. The PhD student plans to submit the cumulative dissertation in summer 2024. She is lead or co-author of the following publications:

Kammann, S., Glaser, K., Hassenrück, C., Karsten, U., Labrenz, M. (202?) Bacterial diversity in biocrusts of sand dunes following a succession gradient. (In preparation)

Kammann, S., Leinweber, P., Glaser, K., Schiefelbein, U., Dolnik, C., Mikhailyuk, T., Demchenko, E., Heilmann, E., Karsten, U. (2024) Successional development of the phototrophic community in biological soil crusts, along with soil formation on Holocene deposits at the Baltic Sea coast. Front. Ecol. Evol. 11:1266209, DOI 10.3389/fevo.2023.1266209

Kammann, S., Karsten, U., Glaser, K., Schiefelbein, U., Dolnik, C., Mikhailyuk, T., Demchenko, E., Leinweber, P. (2023) Cryptogamic vegetation and soil development on holocene deposits on the Baltic Sea Coast. Book of Abstract of 3rd Global Soil Biodiversity Conference, p. 82

Glaser, K., **Kammann, S.,** Plag, N., Dressler, M, (2023) Ecophysiological performance of terrestrial diatoms isolated from biocrusts of coastal sand dunes. Front. Microbiol. 14:1279151. doi: 10.3389/fmicb.2023.127915

Kammann, S., Schiefelbein, U., Dolnik, C., Mikhailyuk, T., Demchenko, E., Karsten, U., Glaser, K. (2023) Successional development of the phototrophic community in biological soil crusts on coastal and inland dunes. MDPI Biology, 12, 58, DOI: 10.3390/biology12010058

The **project IV.2 Sustainability of potato production: cloning and sequencing of candidate genes improving P acquisition efficiency to reduce fertilizer inputs (P-Stop)** started in May 2020. Due to a prolonged illness of the PhD student, the project was extended by the P-Campus for 3 months until July 31, 2023. The submission of the cumulative dissertation is planned for the end of 2024/beginning of 2025. The PhD student is the lead author of the following publication:

Kirchgesser, J., Hazarika, M., Bachmann-Pfabe, S., Dehmer, K. J., Kavka M., Uptmoor, R. (2023) Phenotypic variation of root-system architecture under high P and low P conditions in potato (*Solanum tuberosum* L.). BMC Plant Biology, DOI: 10.1186/s12870-023-04070-9

Two further publications are in progress and are due to be submitted in 2024.

The **project IV.3 The role of inorganic phosphate supply on the development of cyanobacterial summer blooms in the Baltic Sea (Cyanoblooms)** started in November 2019 and ended after a Corona-related extension on March 31, 2023. The submission of the dissertation is planned for May 2024. The PhD student is the lead or co-author of the following publications:

Santoro M., Vanharanta M., Villena-Alemany C., Piiparinen J., Grossart H.P., Spilling K., Sperlea T., Hassenrück C., Piwosz K., Labrenz M. (202?) The impact of a storm event on different cyanobacterial lifestyles in the Western Baltic Sea: a mesocosm case study. (in preparation)

Vanharanta M., Piiparinen J., **Santoro M.**, Villena-Alemany C., Hassenrück C., Labrenz M., Grossart H.P., Piwosz K., Spilling K. (202?) Microbial remineralization processes during post-spring-bloom phosphate conditions in the northern Baltic Sea. (in preparation)

Santoro, M., Hassenrück, C., Labrenz, M., Hagemann, M. (2023) Acclimation of *Nodularia spumigena* CCY9414 to inorganic phosphate limitation - Identification of the P-limitation stimulon via RNA-seq. Front. Microbiol. 13:1082763, DOI: 10.3389/fmicb.2022.1082763

The **project IV.4 Phosphorus as a metabolic regulator during environmental stress in animals (MetaPhos)** started in August 2020 and ended on November 30, 2023. The submission of the dissertation is planned for the first half of 2024. The PhD student is lead or co-author of the following publications:

Adzigbli, L., Sokolov, E. P., Ponsuksili, S., Sokolova, I. M. (2022) Tissue- and substrate-dependent mitochondrial responses to acute hypoxia–reoxygenation stress in a marine bivalve (*Crassostrea gigas*). J Exp Biol 225 (1), DOI: 10.1242/jeb.243304

Adzigbli, L., Sokolov, E.P., Wimmers, K., Sokolova, I.M., Ponsuksili, S. (2022) Effects of hypoxia and reoxygenation on mitochondrial functions and transcriptional profiles of isolated brain and muscle porcine cells. Sci Rep 12(1): 19881, DOI: 10.1038/s41598-022-24386-0

Sokolov, E. P., **Adzigbli, L.**, Markert, S., Bundgaard, A., Fago, A., Becher, D., Hirschfeld, C., Sokolova, I. M. (2021) Intrinsic mechanisms underlying hypoxia-tolerant mitochondrial phenotype during hypoxia-reoxygenation stress in a marine facultative anaerobe, the blue mussel *Mytilus edulis*. Frontiers in Marine Science 8:773734, DOI: 10.3389/fmars.2021.773734

Another manuscript is currently under review.

The **project IV.5 Molecular mechanisms of phosphate homeostasis and osteo-immunological processes and their consequence for health and welfare (P homeostasis)** started in October 2020 and ended on December 31, 2023, after an extension. The dissertation was submitted in January 2024. The PhD student is the lead author of the following publications:

Hasan, M., Reyer, H., Oster, M, Trakooljul, N., Ponsuksilli, S., Magowan, E., Fischer, D.-C., Wimmers, K. (2024) Exposure to artificial ultraviolet-B light mediates alterations on the hepatic transcriptome and vitamin D metabolism in pigs. The Journal of Steroid Biochemistry and Molecular Biology 106428, DOI: 10.1016/j.jsbmb.2023.106428

Hasan, M., Oster, M., Reyer, H., Wimmers, K., Fischer, D.C. (2023) Efficacy of dietary vitamin 3 and 25(OH)D3 on reproductive capacities, growth performance, immunity and bone development in pigs. British Journal of Nutrition 28;130(8):1298-1307. doi: 10.1017/S0007114523000442

Hasan, M., Oster, M., Reyer, H., Ponsuksili, S., Murani, E., Wolf, P., Fischer, D.-C., Wimmers, K. (2022) Tissue-wide expression of genes related to vitamin D metabolism and FGF23 signaling following variable phosphorus intake in pigs. Metabolites 12, 729, DOI: 10.3390/metabo12080729

The **project V. Governance options for closed P cycles - the GAP 2020 revision (P-Governance)** started in July 2019 and ended after a Corona-related extension on September 30, 2022. The dissertation was submitted in the 2nd quarter of 2023 and successfully defended on December 15, 2023.
The PhD student is lead author (8) or co-author (8) of the following publications:

Ekardt, F., Günther, P., Hagemann, K., Garske, B., **Heyl, K.**, Weyland, R. (2023) Legally binding and ambitious biodiversity protection under the CBD, the global biodiversity framework, and human rights law. Environmental Sciences Europe 35, 80. DOI:10.1186/s12302-023-00786-5

Garske, B., **Heyl, K.**, Ekardt, F. (2023) The EU Communication on ensuring availability and affordability of fertilisers – a milestone for sustainable nutrient management or a missed opportunity? Environmental Sciences Europe (in print)

Heyl, K. (2023) Reducing Phosphorus Input into the Baltic Sea—An assessment of the updated Baltic Sea action plan and its implementation through the Common Agricultural Policy in Germany. Water 15(2), 315, DOI: 10.3390/w15020315

Heyl, K., Garske, B., Ekardt, F. (2023) Using bone char as phosphate recycling fertilizer: an analysis of the new EU Fertilising Products Regulation, Environmental Sciences Europe, Environmental Sciences Europe (2023), 35:109. DOI:10.1186/s12302-023-00819-z

Heyl, K., Ekardt, F., Roos, P., Garske, B. (2023) Achieving the nutrient reduction objective of the farm to fork strategy. an assessment of CAP subsidies for precision fertilization and sustainable agricultural practices in Germany. Frontiers in Sustainable Food Systems. 7: 1088640; DOI:10.3389/fsufs.2023.1088640

Heyl, K., Heyl, K., Ekardt, F., Sund, L., Roos, P. (2022) Potentials and limitations of subsidies in sustainability governance: the example of agriculture. Sustainability 14, 15859, DOI: 10.3390/su142315859

Heyl, K., Ekardt, F., Roos, P., Garkse, B. (2022) Digitalisierte Präzisionsdüngung und EU-Agrarsubventionen im deutschen Recht: Ökologisch effektive Umsetzung von Farm-to-Fork-Strategie und Umweltvölkerrecht? Natur und Recht 44, 837–846, DOI: 10.1007/s10357-022-4114-5

Ekardt, F., Bärenwaldt, M., **Heyl, K.** (2022) The Paris target, human rights, and IPCC weaknesses: Legal arguments in favour of smaller budgets. Environments, 9(9), 112, DOI: 10.3390/environments9090112

Ekardt, F., **Heyl, K.** (2022) The German constitutional verdict is a landmark in climate litigation. Nature Climate Change, 12, 697–699, DOI: 10.1038/s41558-022-01419-0

Heyl, K., Ekardt, F. (2022) Barriers and methodology in transitioning to sustainability: Analysing web news comments concerning animal-based diets. Journal of Cleaner Production 330, 129857, DOI: 10.1016/j.jclepro.2021.129857

Heyl, K., Ekardt, F., Roos, P., Stubenrauch, J., Garske, B. (2021) Free Trade, Environment, Agriculture, and Plurilateral Treaties: The Ambivalent Example of Mercosur, CETA, and the EU–Vietnam Free Trade Agreement. Sustainability 13, 3153, DOI: 10.3390/su13063153

Garske, B., **Heyl, K.**, Ekardt, F., Weber, L.M., Gradzka, W. (2021) Lebensmittelverluste als Governance- und Rechtsproblem. NuR 43, 168-179, DOI: 10.1007/s10357-021-3814-6

Stubenrauch, J., Ekardt, F., **Heyl, K.**, Garske, B., Schott, V.L., Ober, S. (2021) How to legally overcome the distinction between organic and conventional farming - Governance approaches for sustainable farming on 100% of the land. Sustain. Prod. Consum. 28, 716-725, DOI: 10.1016/j.spc.2021.06.006

Heyl, K., Döring, T., Garske, B., Stubenrauch, J., Ekardt, F. (2020): The common agricultural policy beyond 2020: A critical review in light of global environmental goals, RECIEL, DOI: 10.1111/reel.12351

Garske, B., **Heyl, K.**, Ekardt, F., Weber, L.M., Gradzka, W. (2020): Challenges of food waste Governance: An Assessment of European legislation on food waste and recommendations for improvement by economic instruments. Land 2020, 9, 231. DOI: 10.3390/land9070231

Garske, B., **Heyl, K**., Ekardt, F., Weber, L. M., Gradzka, W. (2021) Lebensmittelverluste als Governance- und Rechtsproblem, Natur und Recht, 43, 168-179. DOI: 10.1007/s10357-021-3814-6

Table 3b. Subprojects of the Graduate School 2 (PGS 2, 2019-2023, financed by the Leibniz Association), color marking as follows: defended dissertation in green, submitted dissertation in orange, completed projects with planned submission of the dissertation in purple, finished projects without dissertation in blue (as of December 31, 2023)

Project	Participating Partners	Research Focus
I.1 Risks and benefits of rewetting coastal wetlands after agricultural use	UR, IOW	I
I.2 P Pools and mobilization potential in lowlands and coastal regions	UR, LIKAT	I
I.3 Analysis of glyphosate and glufosinate in sea water and as indicator compounds for industrial cropping	IOW, UR	I
II.1 P recycling in animal husbandry	UR, IOW, FBN	II
II.2 Efficiency of recovered phosphorus for monogastric animals	UR, FBN	II
II.3 P efficiency of forage legumes and their capacity to utilize P from recycling products	IPK, UR	II
III.1 Synthesis of novel P-based ligands for complexes to activate small molecules	LIKAT, UR	III
III.2 Application of P-based organocatalysts and biocatalysts for the resolution of racemic carbonates	UR, LIKAT	III
III.3 Synthesis of potential anti-tumor and adhesion-promoting agents by P-based organocatalysis for oncology and biomedical engineering	LIKAT, UMR, INP	III
IV.1 Gene expression in biogeochemical cycling of phosphorus in biological soil crusts of sand dunes of the Baltic Sea	UR, IOW	IV
IV.2 Sustainability of potato production: Cloning and sequencing of candidate genes improving P acquisition efficiency to reduce fertilizer inputs	UR, IPK	IV

Project	Participating Partners	Research Focus
IV.3 The role of inorganic phosphate supply on the development of cyanobacterial summer blooms in the Baltic Sea	UR, IOW	IV
IV.4 Phosphorus as a metabolic regulator during environmental stress in animals	UR, IOW, FBN	IV
IV.5 Molecular mechanisms of phosphate homeostasis and osteoimmunological processes and their consequence for health and welfare	FBN, UMR	IV
V. Governance options for closed P cycles - the CAP 2020 revision	UR, IOW	V

3.4 Publications

In the following, all publications from phosphorus research of the members of the P-Campus from the year 2023 are listed here:

Ahmed, A.A., Leinweber, P., Kühn, O. (2023) Advances in understanding the phosphate binding to soil constituents: A computational chemistry perspective. Science of The Total Environment 887, DOI: 10.1016/j.scitotenv.2023.163692

Al Methyeb, M., Ruppel, S., Eichler-Löbermann, B., Vassilev, N. (2023) The combined applications of microbial inoculants and organic fertilizer improve plant growth under unfavorable soil conditions. Microorganisms 11, 1721, DOI: 10.3390/microorganisms11071721

Avila, C., Argentel-Martínez, L., Campos-Posada, R., Campos-Posada, G., Eichler-Löbermann, B., Lopez, R. (2023) Efecto del estrés salino en el régimen hídrico, concentración de compuestos osmóticamente activos y pigmentos fotosintéticos en cultivares de tomate. Rev. Investig. Agropecuarias, 49 (1), pp. 32-40. DOI: 10.58149/a09g-wv36

Belov, F., Mildner, A., Knaus, T., Mutti, F., von Langermann, J. (2023) Crystallization-based downstream processing of ω-transaminase- and amine dehydrogenase-catalyzed reactions. Reaction Chemistry & Engineering, 8, 1427-1439, DOI: 10.1039/D2RE00496H

Bullaín-Galardis, M., Campos-Posada, R., Campos-Posada, G. Eichler-Löbermann, B., Pruneau, L., Bâ, A., López-Sánchez, R. (2023) Morphological and physiological responses of *Coccoloba uvifera* (L.) L. seedlings of different origin to salt stress. Terra Latinoamericana 41, 1-15, DOI: 10.28940/terra.v41i0.1655

Ekardt, F., Günther, P., Hagemann, K., Garske, B., Heyl, K., Weyland, R. (2023) Legally binding and ambitious biodiversity protection under the CBD, the global biodiversity framework, and human rights law. Environmental Sciences Europe 35, DOI: 10.1186/s12302-023-00786-5

Galardis, M.M.B., Sánchez, R.C.L., Pruneau, L., Eichler-Löbermann, B., Fall, F., Bâ, A. (2023) Using the ectomycorrhizal symbiosis between *Coccoloba uvifera* L. and *Scleroderma bermudense* Coker to restore a degraded coastal sand dune in Cuba. Trees - Structure and Function, DOI: 10.1007/s00468-023-02470-w

Garske, B., Ekardt, F. (2023) Phosphor-Düngung und Wasserrecht auf internationaler, europäischer und nationaler Ebene - Zugleich zu Gewässer-Implikationen des BVerfG-Klima-Beschlusses. Natur und Recht 45, 152–162, DOI: 10.1007/s10357-023-4151-8

Garske, B., Ekardt, F., Stubenrauch, J. (2023) Phosphorus, human rights, and distributive justice. Working Paper, https://www.nachhaltigkeit-gerechtigkeit-klima.de/files/texts/Phosphorus-Justice-WorkingPaper.pdf

Gasser, S. A. A., Nielsen, K., Eichler-Löbermann, B., Armbruster, M., Merbach, I., Franko, U. (2023) Simulating the soil phosphorus dynamics of four long term field experiments with a novel phosphorus model. Soil Use and Management 39, 867-880, DOI: 10.1111/sum.12881

Geist, L., Wolfer, R., Thiem, R., Thielicke, M., Eichler-Löbermann, B., Eulenstein, F., Müller, M. (2023) Alternative starter fertilization strategies in maize (*Zea mays* L.) cultivation: Agronomic potential of microgranular fertilizer and plant growth-promoting microorganisms and their impact on the soil native microbial community. Agronomy 13, 2900, DOI: 10.3390/agronomy13122900

Hasan, M., Oster, M., Reyer, H., Wimmers, K., Fischer, D.C. (2023) Efficacy of dietary vitamin 3 and 25(OH)D3 on reproductive capacities, growth performance, immunity and bone development in pigs. British Journal of Nutrition 28;130(8):1298-1307. doi: 10.1017/S0007114523000442

Heyl, K. (2023) Reducing Phosphorus Input into the Baltic Sea—An Assessment of the updated Baltic Sea Action Plan and its implementation through the Common Agricultural Policy in Germany. Water 15(2), 315, DOI: 10.3390/w15020315

Heyl, K., Ekardt, F., Roos, P., Garske, B. (2023) Achieving the nutrient reduction objective of the Farm to Fork Strategy. An assessment of CAP subsidies for precision fertilization and sustainable agricultural practices in Germany. Front. Sustain. Food Syst. 7:1088640, DOI: 10.3389/fsufs.2023.1088640

Heyl, K., Garske, B., Ekardt, F. (2023) Using bone char as recycled phosphate fertiliser: An analysis of the new EU Fertilising Products Regulation. Environmental Sciences Europe 35, 1-13, DOI: 10.1186/s12302-023-00819-z

Hu, Y., Dehmer, K., Willner, E., Eichler-Löbermann, B. (2023) Specific and intraspecific P efficiency of small-grain legumes as affected by long-term P management. Agronomy 13, 900, DOI: 10.3390/agronomy13030900

Iqbal, M.A., Hadlich, F., Reyer, H., Oster, M., Trakooljul, N., Murani, E., Perdomo-Sabogal, A., Wimmers, K., Ponsuksili, S. (2023) RNA-Seq-based discovery of genetic variants and allele-specific expression of two layer lines and broiler chicken. Evolutionary Applications 16, 6, 1135-1153, DOI: 10.1111/eva.13557

Kammann, S., Karsten, U., Glaser, K., Schiefelbein, U., Dolnik, C., Mikhailyuk, T., Demchenko, E., Leinweber, P. (2023) Cryptogamic vegetation and soil development on holocene deposits on the Baltic Sea Coast. Book of Abstract of 3rd Global Soil Biodiversity Conference, p. 82

Kammann, S., Schiefelbein, U., Dolnik, C., Mikhailyuk, T., Demchenko, E., Karsten, U., Glaser, K. (2023) Successional development of the phototrophic community in biological soil crusts on coastal and inland dunes. MDPI Biology, 12, 58, DOI: 10.3390/biology12010058

Kanwischer, M., Klintzsch, T., Schmale, O. (2023) Stable isotope approach to assess the production and consumption of methylphosphonate and its contribution to oxic methane formation in surface waters. Environ. Sci. Technol. 57 (42), 15904pp., doi: 10.1021/acs.est.3c04098

Kim, D.-G., Kirschbaum, M.U.F., Eichler-Löbermann, B., Gifford, R.M., Liáng, L.L. (2023) The effect of land-use change on soil C, N, P, and their stoichiometries: A global synthesis. Agriculture, Ecosystems & Environment 348, DOI: 10.1016/j.agee.2023.108402

Kirchgesser, J., Hazarika, M., Bachmann-Pfabe, S., Dehmer, K. J., Kavka M., Uptmoor, R. (2023) Phenotypic variation of root-system architecture under high P and low P conditions in potato (*Solanum tuberosum* L.). BMC Plant Biology 23, 68, DOI: 10.1186/s12870-023-04070-9

Koch, S., Lederer, H., Kahle, P., Lennartz, B. (2023) Linking transport pathways and phosphorus distribution in a loamy soil: a case study from a North-Eastern German Stagnosol. Environmental Monitoring and Assessment 195, 933, DOI: 10.1007/s10661-023-11456-6

Koch, S., Rosewig, E.I., Lennartz, B. (2023) Legacy phosphorus in sediments of lowland waterways. Environments 10, 1-15, DOI: 10.3390/environments10030043

Koczorski, P., Furtado, B.U., Baum, C., Weih, M., Ingvarsson, P., Hulisz, P., Hrynkiewicz, K. (2023) Large effect of phosphate-solubilizing bacteria on the growth and gene expression of *Salix* spp. at low phosphorus levels. Front. Plant Sci. 14:1218617, DOI: 10.3389/fpls.2023.1218617

Krieg, J., Stalljohann, G., Oster, M., Pfuhl, R., Reckels, B., Preissinger, W., Weber, M., Meyer, A., Feuerstein, D., Schneider, S. (2023) Stepwise reduction of dietary phosphorus in diets for piglets and fattening pigs of different genetic origin housed under various station environments — A Ringtest. Animals 13, 1774, DOI: 10.3390/ani13111774

Li, S., Siengdee, P., Oster, M., Reyer, H., Wimmers, K. Ponsuksili, S. (2023) Transcriptome changes during osteogenesis of porcine mesenchymal stem cells derived from diferent types of synovial membranes and genetic background. Scientific Reports 13, DOI: 10.1038/s41598-023-37260-4

Medina-Leyva, J., Eichler-Löbermann, B., Campos-Posada, R., Campos-Posada, G., López-Sánchez, R.C., Benavides-Mendoza, A., Rodríguez-Larramendi, L.A. (2023) Phenotypic plasticity of *Anacardium occidentale* L. seedlings exposed to salt stress based on physiological indicators. Terra Latinoamericana 41, 1-11, e1556, DOI: 10.28940/terra.v41i0.1556

Müller, J., Mahnke, B. (2023) Effects of different P-fertilisers on the forage value of grass-clover mixtures. Proceedings of the 22nd Symposium of the European Grassland Federation, Grassland Science in Europe 28, pp. 85-87

Nees, S., Beer, H., Just, P., Teichmeier, L. M., Christoffer, L. E., Guljam, A., Kushik, Braunschweig, H., Hering-Junghans, C. (2023) On the Reactivity of Mes*P(PMe3) towards Aluminum(I) Compounds – Evidence for the Intermediate Formation of Phosphaalumenes (invited contribution). ChemPlusChem, e202300078, DOI: 10.1002/cplu.202300078

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Neuburger, J.E., Gazizova, A., Tiedemann, S., von Langermann, J. (2023) Chemoenzymatic synthesis of enantiopure amino alcohols from simple methyl ketones. European Journal of Organic Chemistry, 26, DOI: 10.1002/ejoc.202201471

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Omotoso, A.O., Reyer, H., Oster, M., Maak, S., Ponsuksili, S., Wimmers, K. (2023) Broiler physiological response to low phosphorus diets at different stages of production. Poultry Science 102, 2, DOI: 10.1016/j.psj.2022.102351

Omotoso, A.O., Reyer, H., Oster, M., Ponsuksili, S., Wimmers, K. (2023) Jejunal microbiota of broilers fed varying levels of mineral phosphorus. Poultry Science 102 (12), DOI: 10.1016/j.psj.2023.103096

Pilopp, Y., Bresien, J., Gschwind, D., Villinger, A., Michalik, D., Schulz, A. (2023) Access to benzo- and naphtho-azaphospholes via C–H bondactivation of aryl-substituted isonitriles. Chem. Eur. J. 29, 33, DOI: 10.1002/chem.202300764

Ponsuksili, S., Hadlich, F., Perdomo-Sabogal, A., Reyer, H., Oster, M., Trakooljul, N., Iqbal, M.A., Schmucker, S., Stefanski, V., Roth, C., Camarinha Silva, A., Huber, K., Sommerfeld, V., Rodehutscord, M., Wimmers, K. (2023) The dynamics of molecular, immune and physiological features of the host and the gut microbiome and their interactions before and after onset of laying in two hen strains. Poultry Science 102, 1, DOI: 10.1016/j.psj.2022.102256

Prüter, J., McLaren, T.I., Pätzig, M., Hu, Y., Leinweber, P. (2023) Phosphorus speciation along a soil to kettle hole transect: sequential P fractionation, P XANES, and ^{31}P NMR spectroscopy. Geoderma 429, 116215 DOI: 10.1016/j.geoderma.2022.116215

Prüter, J., Schumann, R., Klysubun, W., Leinweber, P. (2023) Characterization of phosphate compounds along a catena from arable and wetland soil to sediments in a Baltic Sea lagoon. Soil Syst. 2023, 7, 15, DOI: 10.3390/soilsystems7010015

Santoro, M., Hassenrück, C., Labrenz, M., Hagemann, M. (2023) Acclimation of *Nodularia spumigena* CCY9414 to inorganic phosphate limitation - Identification of the P-limitation stimulon via RNA-seq. Front. Microbiol. 13:1082763, DOI: 10.3389/fmicb.2022.1082763

Schleyken, J., Gumpert, F., Tränckner, S., Palm, H., Tränckner, J. (2023) Enhanced chemical recovery of phosphorus from residues of recirculating aquaculture systems (RAS). Int. J. Environ. Sci. Technol., 1-14, DOI: 10.1007/s13762-023-05226-8

Seyedalmoosavi, M. M., Dannenberger, D., Pfuhl, R., Görs, S., Mielenz, M., Maak, S., Wolf, P., Daş, G., & Metges, C. C. (2023) Lipid metabolism, fatty acid composition and meat quality in broilers supplemented with increasing levels of defrosted black soldier fly larvae. Journal of Insects as Food and Feed 9(5), 583-598, DOI: 10.3920/JIFF2022.0125

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Siebers, N., Kruse, J., Jia, Y., Lennartz, B., Koch, S. (2023) Loss of subsurface particulate and truly dissolved phosphorus during various flow conditions along a tile drain-ditch-brook continuum. Science of the Total Environment 866, DOI: 10.1016/j.scitotenv.2023.161439

Siewert, J.-E., Schumann, A., Wellnitz, T., Dankert, F., Hering-Junghans, C. (2023) Tri-phosphiranes as phosphinidene-transfer agents – synthesis of regular and chelating NHC phosphinidene adducts (invited contribution, HOT Article Collection). Dalton Trans. 52, DOI: 10.1039/D3DT02690F

Siewert, J.-E., Puerta Lombardi, B. M., Jannsen, N., Roesler, R., Hering-Junghans, C. (2023) Synthesis and ligand properties of chelating bis(N-heterocyclic carbene)-stabilized bis(phosphinidenes). Inorg. Chem. 62, DOI: 10.1021/acs.inorgchem.3c02264

Täufer, T., Dankert, F., Michalik, D., Pospech, J., Bresien, J., Hering-Junghans, C. (2023) Photochemical formation and reversible base-induced cleavage of a phosphagallene. Chem. Sci. 14, 3018-3023, DOI: 10.1039/D2SC06292E

Terazzi, C., Spannenberg, A., von Langermann, J., Werner T. (2023) Chemoenzymatic synthesis of chiral building blocks based on the kinetic resolution of glycerol-derived cyclic carbonates. ChemCatChem 2023, 15, e202300917, DOI: 10.1002/cctc.202300917

Thielicke, M., Ahlborn, J., Eichler-Löbermann, B., Eulenstein, F. (2023) On the negative impact of mycorrhiza application on maize plants (*Zea mays*) amended with mineral and organic fertilizer. Microorganisms, 11 (7), No. 1663, DOI: 10.3390/microorganisms11071663

Zander, E., Bresien, J., Zhivonitko, V.V., Fessler, J., Villinger, A., Michalik, D., Schulz, A. (2023) rational design of persistent phosphorus-centered singlet tetraradicals and their use in small-molecule activation. J. Am. Chem. Soc. 2023, 145, 26, 14484–14497, DOI: 10.1021/jacs.3c03928

Zerssa, G.W., Kim, D.-G., Koal, P., Eichler-Löbermann, B. (2023) Grain mineral concentrations in maize (*Zea Mays* L.) and nutrient use efficiency as affected by fertilizer management on a Nitisol in Southwestern Ethiopia. Comm Soil Sci. Plant Anal. 54 (14), 1939-1954, DOI: 10.1080/00103624.2023.2211107

3.5 Theses

In 2023, three P-Campus-funded dissertations were successfully defended (Table 4, *in italics*). In addition, three further dissertations were supervised by P-Campus members. P-Campus members also supervised six Master's theses and four Bachelor's theses. Some of the student theses were co-supervised by PGS2 doctoral students.

Table 4. List of theses in the P-Campus

Thesis	Institution
Dissertations	
Eickhoff, L. H. (2023) Synthesis and Reactivity of Pacman Phosphanes	UR-MNF-CHE
Gupta, P. (2023) Novel phosphaalkene-based late transition metal complexes: Synthesis and applications.	UR-MNF-CHE, LIKAT
Heyl, K. (2023) The reform of the Common Agricultural Policy of the European Union. Assessing subsidies for sustainability transitions and phosphorus management	FNK
Neuburger, J (2023) Integrierte Ansätze in Transaminase-katalysierten Reaktionen und dessen Downstream-Procressing	UR-MNF-CHE
Prüter, J. (2023) Phosphorus speciation in soil and sediment indicating transformation processes from terrestrial to aquatic ecosystems.	UR-AUF-SSC
Siewert, J.-E. (2023) PEt3-katalysierte reduktive Kupplung von Dihalogenphosphanen und die Chemie von NHC-stabilisierten Phosphinidenen.	LIKAT, UR-MNF-CHE
Master Theses	
Burmeister, E. (2023) Räumliche Veränderungen des Boden-Phosphorgehaltes über einen Zeitraum von 22 Jahren in einem agrosilvopastoralen Alley- Cropping-System in Norddeutschland	UR-AUF-AGR
Franke, I. (2023) Aktivität von Enzymen des Phosphorkreislaufes in Abhängigkeit von Düngungsstrategien im Maisanbau	UR-AUF-AGR
Kittmann, L. (2023) Zeitliche Schwankungen von Stickstoff und Phosphor im Boden eines silvoafablen Agroforstsystems	UR-AUF-AGR
Kölling, C. (2023) Molekulare Aufklärung der Rolle von Polyphosphaten in aquatischen Organismen.	UR-MNF, FBN
Patel, P. B. (2023) Transfer of a bio-catalytic process from batch to flow – parameter optimization in a lab-scale flow set-up and implementation of the flow process in pilot scale	UR-MNF-CHE
Thonack, V. (2023) Interspezifische Phosphoreffizienz bei kleinkörnigen Leguminosen.	UR-AUF-AGR
Bachelor Theses	
Gombert, M. (2023) Einfluss des Blatt-Stängel-Verhältnisses von Rotklee und Luzerne auf die Interpretation von Nährstoffanalyse-Ergebnissen	UR-AUF-GF
Gorowski, E. (2023) Untersuchung der Phosphor-Düngewirkung von mineralischen und biologischen Düngepräparaten im Vergleich zur Einzelausbringung von Diammoniumphosphat	UR-AUF-AGR
Richter, K. (2023) Agroforstsysteme in verschiedenen Klimazonen	UR-AUF-AGR
Weingärtner, F. (2023) Räumliche Verteilung von Kohlenstoff und Stickstoffgehalten in einem Agroforstsystem Norddeutschlands	UR-AUF-AGR

Abbreviations: AGR = chair of Agronomy, AUF = Faculty of Agricultural and Environmental Sciences, CHE = Institute for Chemistry, FBN = Institute for Farm Animal Biology, GF = chair of Grassland and Fodder Sciences, MNF = Faculty of Mathematics and Natural Sciences, SSC = chair of Soil Science, UR = University of Rostock

4 Networking

Besides interactions among its individual scientists and research groups, the P-Campus is a member of the European Sustainable Phosphorus Platform (ESPP) and the German Phosphorus Platform (DPP). In addition, the P-Campus is connected with other Leibniz ScienceCampi as well as through its scientists and their thematic networks.

German Phosphorus Platform (DPP) – Participation in the annual DPP forum (10.10.2023, on site), Prof. P. Leinweber (Spokesman of the P-Campus for the University of Rostock)

Associated partnerships with the:

German Chemical Society, working group Phosphorus Chemistry (Prof. Dr. Evamarie Hey-Hawkins, Prof. Dr. Jan J. Weigand, Prof. Dr. Robert Wolf)

University of Copenhagen, Research Group Soil Fertility (Prof. Dr. Lars Stoumann Jensen, Prof. Dr. Jakob Magid, Prof. Dr. Dorette Sophie Müller-Stöver)

- Presentations at the P-Campus Symposium on October 09/10, 2023 at the IOW: Jakob Magid "PROCESSOR: Phosphorus Recycling frOm Complex scarcEly Sol-uble Societal resources – letting the sOil do the work" and Aimée Schryer "Measuring recycled phosphorus amendment availability and transformations within one-dimensional soil microcosms"

New collaborations in the P-Campus:

The P-Campus provided financial support for a **seed project** "Plasma-assisted treatment of biomass and sewage sludge for phosphorus recovery" [**PlaBiPhos**] of the partners INP (Dr. Brüser) and UR (Prof. Tränckner) in the period from October 2022 to January 2023. The aim of the study was to investigate the influence of microwave plasmas on liquid manure and sewage sludge substrates with regard to the effect on the mobilization of phosphate. The experiments carried out here, which had more of a proof-of-concept character due to the short duration of the project, can be investigated in more detail in a subsequent project funded by the Leibniz Association entitled "Advanced Biomass-Treatment for Value-Added Refinement" [**BIOADVAN, K494/2022**]. The BIOADVAN project combines the expertise of the Leibniz Institute for Plasma Science and Technology (INP) in plasma technologies with the expertise of the **Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)** in the processing of biomass and the expertise of the University of Rostock (UR) in the recovery of raw materials from waste (or wastewater).

P. Leinweber's participation in the **"PROCESSOR" project** at the **University of Copenhagen** (Prof. J. Magid, Department of Plant and Environmental Sciences) includes participation in the selection of the scientific staff to be recruited (including Dr. Wakene Negassa, a PhD student in the WG Soil Science, University of Rostock) as well as in the discussion of the first scientific results and planning of further experimental work. In particular, by means of an application to the Canadian synchrotron CLS, measurement time was obtained for samples from the PROCESSOR project and extensive investigations with P-XANES were carried out, initially by sending in the samples and in December also with the personal presence of P. Leinweber at the CLS. A member of the project team from the University of Copenhagen was trained in the P-XANES technique, so that in future the Copenhagen working group will be able to carry out the P-XANES measurements increasingly independently. At a consortium meeting in Copenhagen in June 2023, the scientific results were discussed, from which at least one joint publication will result.

5 Events

The P-Campus has organized and hosted or supported several external and internal events, which are listed in the following.

5.1 Public Events

The **International P-Campus Symposium 2023** of the Leibniz ScienceCampus Phosphorus Research Rostock took place on October 9/10, 2023 as a hybrid conference at IOW. 18 presentations and three posters demonstrated the research results as well as the networking and cooperation within the P-Campus and with scientists outside the P-Campus. P-Campus PhD students presented six lectures. Three members of the International Scientific Advisory Council (SAC) of the P-Campus attended the symposium on site. Two members of the SAC could not attend.

Table 5. Presentations at the International P-Campus Symposium on October 9/10, 2023: presentations by P-Campus PhD students in green, presentations from P-Campus seed projects in purple, presentations by scientists who are not members of the P-Campus are marked with an "E" for external in the column Cluster

Name of the speaker	Presentation	Cluster
Oral presentations		
Sandra Kammann (UR)	Successional development of a diverse community in biological soil crusts at the Baltic Sea coast: Implications in P cycling	IV
Mariano Santoro (IOW)	Phosphate limitation and storms in the Baltic Sea: the diversity of strategies in Cyanobacteria under the spotlight	IV
Uwe Buczko (UR)	The new phosphorus soil fertility classes and their relationships to phytodiversity and vegetation types	II
Jakob Magid (UK)	PROCESSOR: Phosphorus Recycling frOm Complex scarcEly Soluble Societal resources – letting the sOil do the woRk	E
Aimée Schryer (UK)	Measuring recycled phosphorus amendment availability and transformations within one-dimensional soil microcosms	E
Peter Leinweber (UR)	InnoSoilPhos - highlights from the 9-year-funding period	II
Ashour Ahmad	Molecular-level insights into phosphate binding in soil: Recent progress	II
Jan-Erik-Siewert	A journey in low-valent phosphorus chemistry	III
Jan Tönjes	P(III)/P(V) Redox Cycling Catalysis: Advances on Efficient Methods for Phosphorus Mediated Reactions	III
Volker Brüser (INP)	Plasma-assisted treatment of biomass for phosphorus recovery	II
Maruf Hasan (FBN)	Molecular determinants of vitamin D metabolism for improved phosphorus efficiency in pigs	IV
Shuaichen Li (FBN)	Isolation, characterization, and in vitro osteogenic differentiation of porcine synovium-derived mesenchymal stem cell	IV
Adewunmi Omotoso (FBN)	Broiler physiological response to low phosphorus diets at different stages of production	IV
Linda Adzigbli (UR, FBN)	Phosphorus as a metabolic regulator during environmental stress in animals	IV
Felix Ekardt (FNK)	Phosphorus and human sciences: Some core results of the P-Campus	V
Nagarjun Devabhakthini (IPK)	From shoots to roots: Phosphorus Phenotyping in the Leibniz IPK Medicago accessions	II
Klaus J. Dehmer (IPK)	Hydroponics-based phenotyping for nutrient efficiency in potatoes	II
Bettina Eichler-Löbermann (UR)	Recycled Fertilizers for Legumes – Food and Feed from Waste and Air	II

Name of the speaker	Presentation	Cluster
Posters		
C. Kölling, …., T. Goldammer (FBN)	Identification of phosphorus metabolism genes of the fish *Salmo salar* and *Sander lucioperca*	IV
Julian Kirchgesser (IPK)	Root-system architecture and P-acquisition efficiency of two contrasting potato (*Solanum tuberosum* L.) genotypes in various P-environments	IV
Helfried Neumann (LIKAT)	Synthesis and Applications of cataCXium A®	III

The **P-Campus Lecture Series** in 2023 took place online (Table 6). The online offer once again resulted in a higher number of participants and the participation of more external interested parties, as no travel was necessary as with the previous attendance-only events. Scientists working in the field of P research and who are no members of the P-Campus were also recruited for the lectures. Up to 31 people registered for the lectures and up to 13 people actually took part.

Table 6. Topics, lecturers and participants (NP) of the lecture series 2023

Date	Topic	Lecturer	NP[a]
27.04.2023	Enough is enough: Lower phosphorus inflows are still sufficient for resilient phytoplankton in coastal areas	Dr. Maximilian Berthold (Mount Allison University)	13 (31)
01.06.2023	Turnover and transport of phosphorus in soil aggregates – From macroaggregates to nanoparticles	Dr. Nina Siebers (Forschungszentrum Jülich)	10 (13)
22.06.2023	Raman spectroscopy and imaging of fluorescent phosphate-containing samples – Case study for soil and bone inspection	Dr. Kay Sowoidnich (FBH)	6 (7)
14.09.2023	Anthropogenic and natural organic trace substances in the Baltic Sea - Current activities, challenges and future perspectives	Dr. Marion Kanwischer (IOW)	8 (10)
28.09.2023	Agronomic evaluation of secondary phosphorus fertilisers from sewage sludge ash, struvite, and bone char in pot and field experiments	Dr. Kerstin Panten (JKI)	9 (16)
05.10.2023	Root and Rhizosphere traits for soil P mobilization	Dr. Maire Holz (ZALF)	6 (10)
19.10.2023	Global and molecular phosphorus pathways in aquaculture	Prof. Tom Goldammer (FBN)	5 (12)
16.11.2023	Phosphorus Availability and Sources in the North and Southeastern Tropical Atlantic Regions of Africa	Dr. Khanneh Wadinga Fomba (TROPOS)	3 (10)

[a] Notice: The number of participants (NP) is the number of people who actually participated. The number of registered persons is shown below in brackets.

5.2 Internal Meetings and Workshops

Internal meetings and workshops facilitate intensive networking and thematic exchanges between scientists of the P-Campus. In addition to various events for PhD students, an annual campus symposium is held in which all scientists introduce their new projects, present their work, and discuss the results. The Steering Group of the P-Campus meets roughly every two to four months to discuss overarching issues as well as the strategic orientation and further development of the P-Campus. In 2023, the meetings were again held in presence, possibly hybrid.

Meetings of the **steering group** of the P-Campus in 2023: 20.01.; 22.02.; 03.07.; 04.09.; 30.11.

Meeting for **DFG Research Training Group** "PhAMoS - Phosphorus Acquisition, Metabolism and Signaling in aquatic and terrestrial organisms": 19.09.2023

6 Public Relations

The P-Campus and the research of its members have been introduced to external research groups, politicians, government and the general public. A selection of the related events is provided below.

6.1 Oral Presentations (Selection)

Lecture conference of the German Society for Plant Breeding, 13. – 14.09.2023, Halle/Saale, Germany

Hasan, M., Oster, M., Reyer, H., Ponsuksili, S., Murani, E., Trakooljul, N., Magowan, E., Fischer, D.-C., Wimmers, K. Molecular determinants of vitamin D metabolism for improved phosphorus efficiency in pigs.

Li, S., Siengdee, P., Oster, M., Reyer, H., Handlich, F., Trakooljul, N., Sarais, F., Wimmers, K., Ponsuksili, S. Transcriptome and epigenetics changes during osteogenesis of porcine mesenchymal stem cells derived from different genetic background.

Seyedalmoosavi, M.M., Mielenz, M., Görs, S., Daş, G., Metges, C.C. Upcycling of recycled minerals from sewage sludge through black soldier fly larvae (*Hermetia Illucens*): impact on growth and mineral accumulation.

Further presentations

Adzigbli, L., Sokolov, E.P., Ponsuksili, S., Sokolova, I. Metabolic fuel alters responses to hypoxia-reoxygenation stress in marine bivalves. Society of Experimental Biology (SEB) Centenary conference 2023, 04.-07.07.2023, Edinburgh, UK

Hasan, M., Oster, M., Reyer, H., Ponsuksili, S., Murani, E., Trakooljul, N., Magowan, E., Fischer, D.-C., Wimmers, K. (2023): Molecular determinants of vitamin D metabolism for improved phosphorus efficiency in pigs. DGfZ/GfT-Jahrestagung 2022, 13.-14.09.2023, Halle/Saale, Germany

Kammann, S., Karsten, U., Glaser, K., Schiefelbein, U., Dolnik, C., Mikhailyuk, T., Demchenko, E., Leinweber, P. (2023) Cryptogamic vegetation and soil development on holocene deposits on the Baltic Sea Coast. 3rd Global Soil Biodiversity Conference, 13.-15.03.2023 in Dublin, Ireland

Li, S., Siengdee, P., Oster, M., Reyer, H., Handlich, F., Trakooljul, N., Sarais, F., Wimmers, K., Ponsuksili, S. (2023): Transcriptome and epigenetics changes during osteogenesis of porcine mesenchymal stem cells derived from different genetic background. DGfZ/GfT-Jahrestagung 2023, 13.-14.09.2023, Halle/Saale, Germany

Leinweber, P. (2023) „Phosphor im System Boden - Pflanze - Gewässer: Neue Erkenntnisse und Entwicklungen". Lecture at the invitation of the Allianz für Gewässerschutz, 03.11.2023, on the premises of the farmers' association in Rendsburg

Santoro, M., Vanharanta, M., Villena-Alemany, C., Grossart, H.-P., Piiparinen, J., Spilling, K., Hassenrück, C., Piwosz, K., Labrenz, M. Insights into adaptational strategies of blooming Cyanobacteria to nutrient limiting conditions and natural perturbation events: a mesocosm study in the Baltic Sea. Symposium on Aquatic Microbial Ecology - SAME17, 20.-25.08.2023, Tartu, Estonia

Seyedalmoosavi, M.M., Mielenz, M., Görs, S., Daş, G., Metges, C.C. Upcycling of recycled minerals from sewage sludge through black soldier fly larvae (*Hermetia Illucens*): impact on growth and mineral accumulation. International Sustainable Resource Recovery Strategies Toward Zero Waste (FULLRECO4US), 13.-15.09.2023, Istanbul, Turkey

Tiedemann, S., Belov, F., Neuburger, J., Gazizova, A., von Langermann, J. Application of crystallization techniques for downstream processing and in situ-product removal in biocatalysis. Swiss-German-Japanese Workshop on Biocatalysis, 12.09.2023, Inuyama, Japan

Other Events

On 24 May 2023, the event "**Perspectives of Phosphorus Research Rostock**" was organized by the P-Campus in the auditorium of the University of Rostock. The directors of the Leibniz Institutes, the Rector of the University of Rostock, representatives of the MV Ministry of Agriculture and the MV Ministry of Science, LUNG and StALUMM were invited to this event. At this event, the development of the P-Campus since 2015, the future of the P-Campus after 2023 and selected current research were presented. After welcoming speeches by Minister B. Martin from the Ministry of Science MV and the Vice-Rector for Research, Talent Development and Equal Opportunities at the University of Rostock, Prof. Wrage-Mönnig, as well as an overview presentation on the status of the P-Campus and an assessment by the scientific advisory board, the following presentations from current P-research were presented:

Dr. A. Zacher (UR) „Neue Wege im Pflanzenbau steigern die P-Effizienz"
Dr. M. Kanwischer (IOW) „Bestimmung von Glyphosat in der Ostsee - eine methodische Herausforderung"
Prof. K. Wimmers (FBN), Prof. C. C. Metges, Prof. J. Tränckner „Ressourcenschonende Nutzung von P aus pflanzlichen Quellen und Rezyklaten in der Tierhaltung"
Prof. T. Werner (LIKAT), Prof. J. v. Langermann „P-Katalyse für die effiziente stoffliche Nutzung von CO_2"
K. Heyl (FNK, UR) „Chancen und Grenzen der GAP für nachhaltiges P-Management"
S. Kammann (UR) „Die Relevanz von biologischen Boden-krusten im P-Kreislauf"
Prof. M. Hagemann (UR), Prof. M. Labrenz, M. Santoro „P-Relevanz für Cyanobakterienblüten in der Ostsee"
Prof. B. Eichler-Löbermann (UR) „P-Effizienz von Leguminosen"
Dr. M. Oster (FBN), PD Dr. S. Wimmers, Prof. I. Sokolova, Prof. D.-C. Fischer „Der Einfluss des P-Stoffwechsels auf die Gesundheit und die Antwort auf Umweltstress bei Tieren"
Prof. J. Tränckner (UR), Dr. S. Tränckner „Stoffkreisoptimierung durch Fraktionierung von Gülle in Phosphor, Stickstoff und organischen Kohlenstoff"
Prof. T. Werner (LIKAT), Prof. I. Sokolova (UR) „Abschlussvortrag: Zukunft des P-Campus nach 2023"

In spring 2020, a **taster day for pupils** in year 11 at the Catholic Niels Stensen School in Schwerin was due to take place at the University of Rostock. Unfortunately, this on-site event had to be canceled due to coronavirus restrictions. The student taster day then took place on July 11, 2023. P-Campus members at the AUF and the Institute of Chemistry presented the degree programs and current research on the element P. The professorships of Soil Science, Crop Production, Agricultural Technology & Process Engineering and Aquaculture & Sea Ranching were involved at the AUF and the Inorganic Chemistry working group in Chemistry.

No joint date could be found in December 2023 for the **2023 end-of-year meeting** between members of the P-Campus and representatives of the Ministry of Agriculture and the Ministry of Science MV, so the meeting took place on January 18, 2024 as an in-person event in the building of the Department of Life, Light and Matter at the University of Rostock. In addition to the presentation on the general development and future of the P-Campus (by D. Zimmer, U. Bathmann), the following lectures from the P-Campus were presented:

„Gemischte Baumbestände: Wie können sie die P-Nutzungs-effizienz im Forst steigern? – Mykorrhizierungsuntersuchungen im Rahmen des DFG-Projektes MixForChange", Prof. Christel Baum (UR-AUF, Professorship of Soil Biology)

„Plasmaunterstützte Prozesse zur Biomassebehandlung", Dr. Volker Brüser (INP)

„P-bedingte Veränderungen des Transkriptoms und der Morphologie der Nebenschilddrüsen beim Schwein", Prof. Klaus Wimmer (FBN), Dr. Michael Oster (FBN), Dr. Jonas Keiler (UMR)

6.2 Posters (Selection)

Adzigbli, L., Sokolov, E.P., Ponsuksili, S., Sokolova, I. Effects of hypoxia and reoxygenation (H/R) on mitochondrial functions and transcriptional profiles of isolated brain and muscle porcine cells. Society of Experimental Biology (SEB) Centenary conference 2023, 04.-07.07.2023, Edinburgh, UK

Belov, F., Bork, H., Gröger, H., von Langermann, J. Transaminase-catalyzed crystallization-assisted synthesis of enantiopure β-methylphenethylamine. Biotrans 2023, 25.-29.06.2023, La Rochelle, Frankreich

Hu, Y. Recycling products affect phosphorus efficiency of forage legumes in a two-year field trial. BonaRes Conference 2023, 15.-17.05.2023, Berlin

Kirchgesser, J., Kavka, M., Hazarika, M., Stetter, K., Bachmann-Pfabe, S., Dehmer K. J., Uptmoor, R. Root-system architecture and P-acquisition efficiency of two contrasting potato (Solanum tuberosum L.) genotypes in various P-environments. GPW-Tagung 2023, 04.-06.10.2023, Göttingen

Müller, J., Mahnke, B. Effects of different P-fertilisers on the forage value of grass-clover mixtures. 22nd EGF Symposium European Grassland Federation, 11.-14.06.2023, Vilnius, Litauen

Neuburger, J., Tiedemann, S., Belov, F., Gazizova, A., von Langermann, J. Preparative implementation of in situ-product crystallization in semi-continuous amine transaminase-catalyzed reactions. Biotrans 2023, 25.-29.06.2023, La Rochelle, Frankreich

Terazzi, C., Spannenberg, A., von Langermann, J., Werner T. From glycerol to pharmaceuticals: Enzymatic kinetic resolution of cyclic carbonates. Sustainable Future: Dream Reactions with (and without) Hydrogen, 24.08.2023, Münster

6.3 Press

Rostocker Forscherin untersucht Ostseedünen und findet "kleine Startups" – Press release of the University of Rostock, 13.02.2023

Rostockerin erforscht als eine der ersten Bodenkrusten und trägt zum Küstenschutz bei - article in the newspaper „Ostsee-Zeitung", p. 17, 24.03.2023

Ostseedünen als Klimaschützer - radio report on NDR, 18.04.2023

Neue Nutztierhaltung: Spiele für Schweine, Laub für Schafe – TV report on „NDR-Nordmagazin". „Mehr Lebensqualität für Nutztiere und klimafreundliches Futter – daran forschen Wissenschaftler im FBN in Dummerstorf.", 13.09.2023

6.4 Websites

Project website **InnoSoilPhos** - **Inno**vative solutions to sustainable **Soil Phos**phorus management: https://www.innosoilphos.de/

Leibniz ScienceCampus Phosphorus Research Rostock: www.wissenschaftscampus-rostock.de (www.sciencecampus-rostock.de | www.p-campus-rostock.de)

Leibniz-Association/ScienceCampi: www.leibniz-gemeinschaft.de/en/research/leibniz-sciencecampi/phosphorous-research

7 Structure and Committees

7.1 Structure

The Leibniz ScienceCampus Phosphorus Research Rostock is assigned to the University of Rostock's Interdisciplinary Faculty (INF), Department of Maritime Systems.

The organisation of the Leibniz ScienceCampus Phosphorus Research Rostock is as follows:
The **Directorship** is made up of the Directors of the participating Leibniz Institutes and the Rector of the University of Rostock. They can be represented by members of their institutions. Through the **Steering Committee** representatives of the Leibniz Institutes and the University of Rostock assume direct leadership of the P-Campus. They are represented by a **Spokesperson**. A staff scientist, supported by a secretary, carries out direct **coordination**. An international **Scientific Advisory Council** oversees the Leibniz ScienceCampus Phosphorus Research and in addition to advising has the task of evaluating the scientific work of the P-Campus. Currently, more than 70 scientists and more than 15 PhD students from 40 Working Groups are **Members** of the P-Campus. This list is constantly updated on the website.

The Leibniz Institute for Baltic Sea Research Warnemünde acts as beneficiaries and provides the coordination office.

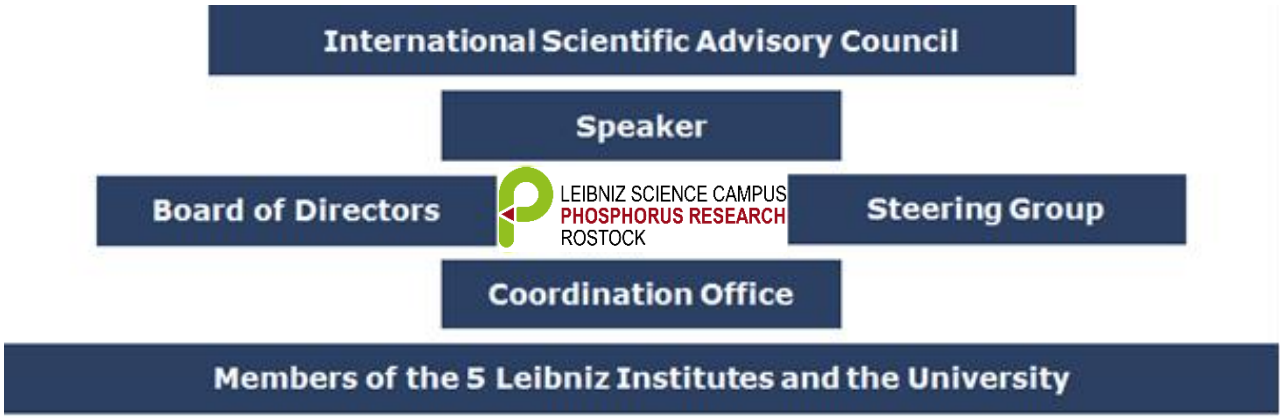

Figure 4. Structure of the Leibniz ScienceCampus Phosphorus Research Rostock

7.2 Committees

7.2.1 Scientific Advisory Council

Prof. Dr. Emmanuel Frossard, ETH Zürich, Switzerland
Prof. Dr. Ellery D. Ingall, Georgia Institute of Technology, USA
Prof. Dr. Helen Jarvie, University of Waterloo, Canada
Prof. Dr. Christian Müller, FU Berlin, Germany
Prof. Dr. Heidrun Steinmetz, TU Kaiserslautern, Germany

7.2.2 Directorship

Prof. Dr. Matthias Beller, LIKAT
Prof. Dr. Elizabeth Prommer, UR
Prof. Dr. Nicolaus von Wirén, IPK
Prof. Dr. Klaus-Dieter Weltmann, INP
Prof. Dr. Klaus Wimmers, FBN
Prof. Dr. Oliver Zielinski, IOW

7.2.3 Spokesperson / Deputy

Prof. Dr. Ulrich Bathmann, IOW
Prof. Dr. Peter Leinweber, UR (spokesperson of the university)

7.2.4 Steering Committee

Prof. Dr. Ulrich Bathmann, IOW
Dr. Volker Brüser, INP
Dr. Klaus Dehmer, IPK
Prof. Dr. Bettina Eichler-Löbermann, UR
PD Dr. Dagmar-Christiane Fischer, UniMed Rostock
Dr. Marion Kanwischer, IOW
Prof. Dr. Ulf Karsten, UR
Prof. Dr. Udo Kragl, UR
Prof. Dr. Peter Leinweber, UR
Prof. Dr. Inna Sokolova, UR
Prof. Dr. Thomas Werner, LIKAT/University of Paderborn

Prof. Dr. Klaus Wimmers, FBN
Dr. Dana Zimmer, P-Campus

Substitutes:
Dr. Christian Hering-Junghans, LIKAT
Dr. Michael Oster, FBN
Prof. Dr. Axel Schulz, UR/LIKAT

7.2.5 Coordination Office

(Work and tasks 2023: see appendix)
Dr. Dana Zimmer (Coordinator)
Maxi Hoche (Secretary)

7.2.6 Members

(Status: Updated during 2023)

Leibniz Institute for Catalysis (LIKAT) at the University of Rostock

Prof. Dr. Matthias Beller	Applied Homogeneous Catalysis	Cluster III
Prof. Dr. Armin Börner	Asymmetric Catalysis	Cluster III
Prof. Dr. Marko Hapke	Cycloadditions and Transition Metal Catalysis	Cluster III
Dr. Christian Hering-Junghans	Small Molecule Activation	Cluster III
Dr. Yuya Hu	Organocatalysis	Cluster III
Dr. Dirk Michalik	Analytical Service	Cluster III
Jan-Erik Siewert	Activation of small molecules	Cluster III
Constanza Terazzi	Organocatalysis	Cluster III
Jan Tönjes	Organocatalysis	Cluster III
Prof. Dr. Thomas Werner	Organocatalysis	Cluster III

Research Institute for Farm Animal Biology (FBN), Dummerstorf

Linda Adzigbli	Genome Biology	Cluster IV
Prof. Dr. Tom Goldammer	Genome Biology	Cluster IV
Maruf Hasan	Genome Biology	Cluster IV
Prof. Dr. Cornelia Metges	Institute of Nutritional Physiology "Oskar Kellner"	Cluster IV
Dr. Michael Oster	Genome Biology	Cluster IV
Mohammad Seyed Al-moosavi	Institute of Nutritional Physiology "Oskar Kellner"	Cluster II
Prof. Dr. Klaus Wimmers	Genome Biology / Director	Cluster II, IV
PD Dr. Siriluck Wimmers	Genome Biology	Cluster IV

Leibniz Institute for Baltic Sea Research (IOW), Warnemünde

Prof. Dr. Ulrich Bathmann	Directorate	Cluster I
Prof. Dr. Michael Böttcher	Geochemistry and Stable Isotope Biogeochemistry	Cluster I, Q
Dr. Philipp Braun	Microbial Processes and Phosphorus Cycle	Cluster I
Dr. Marion Kanwischer	Organic Contaminants	Cluster I, Q
PD Dr. Matthias Labrenz	Environmental Microbiology	Cluster I

Dr. Thomas Neumann	Baltic Sea System Dynamics	Cluster I
Dr. Sarah Piehl	Coastal and Marine Management	Cluster I
Dr. Hagen Radtke	Baltic Sea System Dynamics	Cluster I
Mariano Santoro	Environmental Microbiology	Cluster IV
Dr. Oliver Schmale	Biogeochemistry Trace Gases	Cluster I, Q
Prof. Dr. Detlef Schulz-Bull	Organic Contaminants	Cluster I, Q
Dr. Evgeny Sokolov	Directorate	Cluster IV
Dr. Angela Vogts	NanoSIMS Lab	Cluster Q
Dr. Dana Zimmer	Coordination Office	Cluster II

Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Satellite Collections North, Groß Lüsewitz

Dr. Klaus J. Dehmer	Genebank, Satellite Collections North	Cluster II
Nagarjun Devabhakthini	Genebank, Satellite Collections North	Cluster II
Mousumi Hazarika	Genebank, Satellite Collections North	Cluster II
Yue Hu	Genebank, Satellite Collections North	Cluster II
Dr. Mareike Kavka	Genebank, Satellite Collections North	Cluster II

Leibniz Institute for Plasma Science and Technology (INP), Greifswald

Dr. Volker Brüser	Plasma Process Technology	Cluster II
Prof. Dr. Klaus-Dieter Weltmann	Director	

University of Rostock (UR)

Faculty of Agricultural and Environmental Sciences

Prof. Dr. Christel Baum	Soil Science	Cluster II
Dr. Adrian Bischoff-Lang	Aquaculture and Sea-Ranching	Cluster I, II
Dr. Uwe Buczko	Landscape Ecology and Site Evaluation	Cluster I
Dr. Jörg Burgstaler	Agricultural Technology and Process Engineering	Cluster II
Dr. Carsten Croonenbroeck	Agricultural Economics	Cluster II
Prof. Dr. Bettina Eichler-Löbermann	Agronomy	Cluster II
Dr. Beatrice Garske	Research Unit Sustainability and Climate Policy	Cluster II
Prof. Dr. Bärbel Gerowitt	Crop Health	Cluster II
Felix Gumpert	Water Resources Management	Cluster II
Sebastian Heller	Grassland and Fodder Sciences	Cluster I
Katharine Heyl	Research Unit Sustainability and Climate Policy	Cluster V
Prof. Dr. Florian Jansen	Landscape Ecology and Site Evaluation	Cluster I
Julian Kirchgesser	Agronomy	Cluster II
Dipl. Agr.-Ing. Ulrich Knaus	Aquaculture and Sea-Ranching	Cluster I, II
Dr. Stefan Koch	Soil Physics	Cluster I
Prof. Dr. Peter Leinweber	Soil Science	Cluster II,Q
Prof. Dr. Bernd Lennartz	Soil Physics	Cluster I, II

Dr. Gert Morscheck	Waste Management and Material Flow	Cluster II
Mohsen Morshedizad	Soil Science	Cluster II
Dr. Jürgen Müller	Landscape Ecology and Site Evaluation	Cluster I
Prof. Dr. Michael Nelles	Waste Management and Material Flow	Cluster II
Prof. Dr. Harry Palm	Aquaculture and Sea-Ranching	Cluster I, II
Kristin Steinfurth	Landscape Ecology and Site Evaluation	Cluster I
Prof. Dr. Jens Tränckner	Water Resources Management	Cluster II
Prof. Dr. Ralf Uptmoor	Agronomy	Cluster II
Paul Winklhofer	Crop Health	Cluster II
Prof. Dr. Nicole Wrage-Mönnig	Grassland and Fodder Sciences	Cluster II
Dr. Anika Zacher	Soil Science	Cluster II

Faculty of Law

Prof. Dr. Dr. Felix Ekardt	Research Unit Sustainability and Climate Policy	Cluster V

Faculty of Mathematics and Natural Sciences

Dr. Ashour Ahmed	Institute of Physics, Molecular Quantum Dynamics	Cluster Q
Dr. Martin Albrecht	Institute for Biological Sciences, Applied Ecology & Phycology	Cluster I
Dr. Maximilian Berthold	Institute for Biological Sciences, Applied Ecology & Phycology	Cluster I, Q
Dr. Jonas Bresien	Institute for Chemistry, Anorganic Chemistry	Cluster III
PD Dr. Stefan Forster	Institute for Biological Sciences, Marine Biology	Cluster I
Prof. Dr. Martin Hagemann	Institute for Biological Sciences, Animal Physiol-ogy	Cluster II
Sandra Kammann	Institute for Biological Sciences, Applied Ecology & Phycology	Cluster IV
Prof. Ulf Karsten	Institute for Biological Sciences, Applied Ecology & Phycology	Cluster I, II
Prof. Udo Kragl	Institute for Chemistry, Analytical & Technical Chemistry; Technical Chemistry	Cluster III
Prof. Oliver Kühn	Institute of Physics, Molecular Quantum Dynamics	Cluster Q
Prof. Dr. Axel Schulz	Institute for Chemistry, Anorganic Chemistry	Cluster III
PD Dr. Rhena Schumann	Institute for Biological Sciences, Applied Ecology & Phycology, Biological Station Zingst	Cluster I, Q
Prof. Dr. Inna Sokolova	Marine Biology	Cluster II
Dr. Jan von Langermann	Institute for Chemistry, Biocatalysis	Cluster III

Rostock University Medical Center		
PD Dr. Hugo Murua Escobar	Hematology, oncology and palliative care	Cluster III
PD Dr. Dagmar-Christiane Fischer	Pediatric Clinic, Experimental Pediatrics Group	Cluster II
Prof. Dr. Christian Junghanß	Internal medicine, haematology, oncology, palliative ward	
Dr. Jonas Keiler	Institute for Anatomy	
Prof. Dr. Brigitte Vollmar	Institute for Experimental Surgery, University Medicine Rostock	Cluster II

7.2.7 Associated members

German Chemical Society, Working Group Phosphorus Chemistry

Prof. Dr. Evamarie Hey-Hawkins
Prof. Dr. Jan J. Weigand
Prof. Dr. Robert Wolf

University of Copenhagen, Research Group Soil Fertility

Prof. Dr. Lars Stoumann Jensen
Prof. Dr. Jakob Magid
Prof. Dr. Dorette Sophie Müller-Stöver

8 Funding

The financial requirements in 2023 were covered by funding from the Ministry of Science, Culture, Federal and European Affairs Mecklenburg-Vorpommern (SM-MV), the Ministry for Climate Protection, Agriculture, Rural Areas and the Environment Mecklenburg-Vorpommern (AM-MV) funding from the Leibniz Association and considerable contributions from the participating Leibniz Institutes and the University of Rostock. External funding by third parties for phosphorus research at the P-Campus was obtained as well (Table 1).

In 2023, the coordination office of the P-Campus was funded by the SM-MV with 38,996 euros (01.01.2023 until 30.04.2023) and by the AM-MV with 77,975.30 euros (01.05.2023 until 31.12.2023). Since 2014, the Coordination Office, located at the IOW, has consisted of two employees: a scientist and a secretary.

Since 2015, the P-Campus had an amount of € 1.2 million at his disposal, provided by the Leibniz Association, to be distributed over a period of four years to i.a. partially fund 11 interdisciplinary PhD projects. From June 2019 on, the Leibniz Association provides a total amount of € 1.13 million within the scope of the second funding period of the P-Campus.

With the completion of the second P-Campus graduate school on March 31, 2024, it can be calculated that the WGL for PGS 1 + PGS 2 and the two ministries (for the coordination office) together provided approximately € 3.2 million for the P-Campus. At the same time, 60 third-party funded projects (excluding PGS 1 + 2) totalling more than €43 million were acquired by the P-Campus members. This means that from 2015 to 2023, the

P-Campus members raised around 13 times more funding than the WGL and the ministries.

Table 7. Comparison of the financing of the P-Campus

Type of funding	Financial resources in €
Funding by WGL (PGS 1: 2015 to 2019 + PGS 2: 2019 to 31.03.2024)	2,332,800 €
Funding P-Campus coordination office by ministries[a] (01/2015-12/2023)	927,478 €
Sum WGL and ministries	3,260,278 €
Own resources (Leibniz)-Institutes + University of Rostock for PGS 2 from 2019 to end 2022! (feedback for 2023 still incomplete)	ca. 3.1 Mio € (ca. 900,000 € estimated)
Sum of funding from WGL, ministries and P-Campus partners (rounded)	ca. 4.2 Mio €
Total financial volume Third-party funded projects with start from 2015 to end of 2023 (without PGS 1 and PGS 2)	>43 Mio €

[a] Ministry of Science, Culture, Federal and European Affairs Mecklenburg-Vorpommern und Ministry for Climate Protection, Agriculture, Rural Areas and the Environment Mecklenburg-Vorpommern

APPENDIX

Contents

Leibniz ScienceCampus Phosphorus Research Rostock

Tasks of the Coordination Office 2023

In the following, the activities and thematic foci of the Coordination Office of the Leibniz ScienceCampus Phosphorus Research Rostock in 2023 are described. The coordination position has been occupied by Dr Dana Zimmer (scientific coordination) since October 2018 and Maxi Hoche (secretariat) since September 2019. The focus of the Coordination Office's work was, as before, the coordination of the partner institutions and its individual members, research foci and projects and, from June 2019, the organization of the P-Campus Graduate School of the new funding phase of the Leibniz Association (PGS2). Other tasks included i. a. the external representation of the P-Campus (e.g. regular website update), the preparation of reports and emails providing information to interested parties, the organization of other events of different formats (e.g. lecture series) and financial management (together with the administration department of the IOW). The work was carried out in close coordination with the spokesperson and the steering group of the P-Campus.

In the following, the priorities of the Coordination Office, including its function as a contact point, provider of support in the development of research project proposals, coordinator of the graduate school, event organizer as well as its public relations tasks are described in detail.

Contact point

The Coordination Office of the P-Campus is the linchpin for networking, both within the P-Campus and externally, at national and international levels. In 2023, the Coordination Office continued to serve as a contact for all members of the P-Campus, new members and external persons and handled external inquiries, and forwarded targeted information to the relevant members/member groups. By mediating both internal and external contacts, the office supported networking among scientists.

Contacts with **external research institutes, ministries and authorities** were regularly maintained (e.g. 18.01.2024 presentation of recent research results of the P-Campus to ministry members). Furthermore, there are contacts with **other networks**, e.g. the INF (Interdisciplinary Faculty), and the German Phosphorus-Platform (DPP).

In autumn 2023, the coordination office established contact for the head of the Zingst Biological Station (Dr. Rhena Schumann) with IOW staff (S. Piehl, R. Friedland) and the LUNG (C. Engelke, M. von Weber) due to anomalies in the bottom water analysis data of the Darß-Zingst Boddenkette compared to the long-term data. A cooperation regarding the respective long-term data and an integration of the study area and the data of the Darß-Zingst Boddenkette into a third-party funded project of the IOW starting in 2024 was agreed.

Research topics and initiatives

The P-Campus thrives on the continuous initiatives of its scientists in developing research themes and ideas and in considering proposals for their realization. The funding of six new **seed projects** could be supported by the P-Campus with the official start of the second funding period in June 2019. All six projects have been successful, and since 2022 all final reports are available in the coordination office. In the summer and autumn of 2022, a call for seed projects was initiated by the coordination office with regard to the envisaged **Leibniz Research Network** "P-Health - Phosphorus in Agriculture, Environment and Nutrition: Ecological Consequences and Societal Challenges" and the **DFG Re-**

search Training Group "PhAMoS - Phosphorus Acquisition, Metabolism and Signaling in aquatic and terrestrial organisms". Eleven seed projects were approved. Both initiatives are to become the successor projects for the current Leibniz Science Campus funding after 2023 at the latest. For this purpose, the P-Campus Coordination Office organized appropriate meetings for both initiatives in 2022. At the colloquium "Perspectives on phosphorus research Rostock" (May 24, 2023) respectively at the **International P-Campus Symposium** (October 9/10, 2023), both research initiatives were presented to representatives of the Leibniz Institutes, the University of Rostock, the Ministry of Science, Culture, Federal and European Affairs MV (WM-MV), StaluMM, the Scientific Advisory Board and the members of the P-Campus.

Structured graduate support

As young scientists are a significant part of the P-Campus network, a structured framework for their support and encouragement is offered by the P-Campus. The Coordination Office is responsible for the coordination and administration of the new graduate school and will organize several events and other networking opportunities for the PhD students again. Since June 2019, the new PhD students were gradually employed (last employment in October 2020). After the **start workshop P-Analytics** in November 2019 and the **P-Breakfast** in December 2019, no face-to-face events for PhD students could be organised by the coordination office until 2022 due to the restrictions caused by the pandemic. In 2022, a workshop and a P-Breakfast were possible again. As some PhD students had already completed their dissertation in 2023 and all others were in the final phase of their dissertation, the Coordination Office no longer organized any workshops or P breakfasts to ensure that the PhD students could concentrate fully on completing the project and their dissertation.

In 2023, the annual P-Campus lecture series with a total of eight lectures was organised by the P-Campus Coordination Office. Six of these lectures were presented by scientists from institutes outside the P-Campus. The **International P-Campus Symposium** took place in October 2023 as a hybrid event. At this symposium, which was also attended by representatives of the International Scientific Advisory Board, 18 lectures and three posters were presented in total. Seven of these were presentations from PhD projects and three from P-Campus seed projects.

Due to the pandemic, some PhD projects of the PGS2 were not able to carry out their research in 2020, 2021 and partly in 2022 as planned, resulting in time delays. As in the previous years, the coordination office also took care of the approval of additional funding for these PhD projects in 2023.

Event organization

The events organized and guided by the Coordination Office are an important basis not only for networking but also for the internal and external representation of the P-Campus. In 2023, this included i. a. the organization of the P-Campus **Steering Group** meetings (including the presentation of current developments, taking minutes, etc.), the **International P-Campus Symposium** (hybrid format) in October 2023, the organization of the **annual year-end meeting** (on-site event in January 2024) between representatives of the P-Campus and the Ministry of Science, Culture, Federal and European Affairs MV and the Ministry for Climate Protection, Agriculture, Rural Areas and the Environment MV, respectively, as well as the organisation of the lecture series (see above).

On May 24, 2023, the event "**Perspectives on Phosphorus Research Rostock**" was organized by the P-Campus coordination office in the auditorium of the University of Rostock. The directors of the Leibniz Institutes, the Rector of the University of Rostock, representatives of the Science Ministry MV and Agriculture Ministry MV, the LUNG and the StALUMM were invited to this event. At this event, the development of the P-Campus since 2015, the future of the P-Campus after 2023 and selected current research were presented. After the welcoming speeches by Minister B. Martin from the Science Ministry MV and the Vice-Rector for Research, Talent Development and Equal Opportunities of the University of Rostock, Prof. Wrage-Mönnig, as well as an overview presentation on the status of the P-Campus (D. Zimmer, coordinator; U. Bathmann, spokesperson of the P-Campus) and an assessment by the scientific advisory board, ten presentations from current P-research and a presentation on the planned future of the P-Campus were presented.

In spring 2020, a **taster day for pupils** in year 11 at the Catholic Niels Stensen School in Schwerin was due to take place at the University of Rostock. Unfortunately, this on-site event had to be cancelled due to coronavirus restrictions. The school taster day was then organized by the coordination office for July 11, 2023. P-Campus members at the Faculty of Agricultural and Environmental Sciences and the Institute of Chemistry presented the degree programs and current research on the element P. The professorships of Soil Science, Crop Production, Agricultural Technology & Process Engineering and Aquaculture & Sea Ranching were involved in the AUF and the Inorganic Chemistry working group in Chemistry.

Public relations

The P-Campus is a prominent research network among six partner institutions in Mecklenburg-Vorpommern and is represented not only regionally but also nationally and internationally. The coordination office is responsible for the presentation of the P-Campus at various **events** and in the **media** (articles, interviews).

In 2023, scientists from the P-Campus once again presented various research topics from the P-Campus to a broad public at the "Long Night of Sciences" at the University of Rostock and the Leibniz Institutes.

Moreover, the development and **provision of information** (handouts, posters, presentations) about the P-Campus is part of the tasks of the coordination office. That also means that members of the P-Campus are actively addressed to represent the P-Campus at interesting events (conferences, workshops etc.). Selected workshops and other small events are used to increase the level of awareness of the P-Campus and attract new members by **offering P-Campus advertising material** (writing pads, cloth bags, flyers, etc.). These measures were only possible to a limited extent in 2023. The P-Colloquium in May and the P-Campus Symposium in October were used in particular.

The coordination office offers support related to introducing the P-Campus to external scientific groups, policy makers, authorities, and the general public through visual presentations, such as research posters. For this purpose, appropriate **templates** and information are prepared and provided to the members. Another important task was the design and maintenance of the **website** including content development, in coordination with relevant scientists. The website is updated continuously with new information from the P-Campus (e.g. new publications, P relevant events). Furthermore, the coordination office compiles texts and information that allow the presentation of the P-Campus on other websites (for example, those of the DPP and the ESPP).

Cooperation Partners:

Leibniz Institute for Baltic Sea Research Warnemünde (IOW)
Prof. Dr. Oliver Zielinski (Director)
Seestr. 15
18119 Rostock

Leibniz Institute for Catalysis (LIKAT), Rostock
Prof. Dr. Matthias Beller (Director)
Albert-Einstein-Str. 29a
18059 Rostock

Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Satellite Collections North, Groß Lüsewitz
Prof. Dr. Nicolaus von Wirén (Director)
Parkweg 3a
18190 Groß Lüsewitz

Leibniz Institute for Plasma Science and Technology (INP), Greifswald
Prof. Dr. Klaus-Dieter Weltmann (Director)
Felix-Hausdorff-Str. 2
17489 Greifswald

Research Institute for Farm Animal Biology (FBN), Dummerstorf
Prof. Dr. Klaus Wimmers (Director)
Wilhelm-Stahl-Allee 2
18196 Dummerstorf

University of Rostock
Prof. Dr. Elizabeth Prommer (Rector)
Universitätsplatz
18055 Rostock

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Leibniz ScienceCampus Phosphorus Research Rostock

c/o Leibniz Institute for Baltic Sea Research Warnemünde

Seestr. 15

18119 Rostock

Germany

info@sciencecampus-rostock.de

www.sciencecampus-rostock.de

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Dr. Dana Zimmer
Maxi Hoche

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Katalysis
Leibniz-Institut für Katalyse e.V.
LIKAT
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