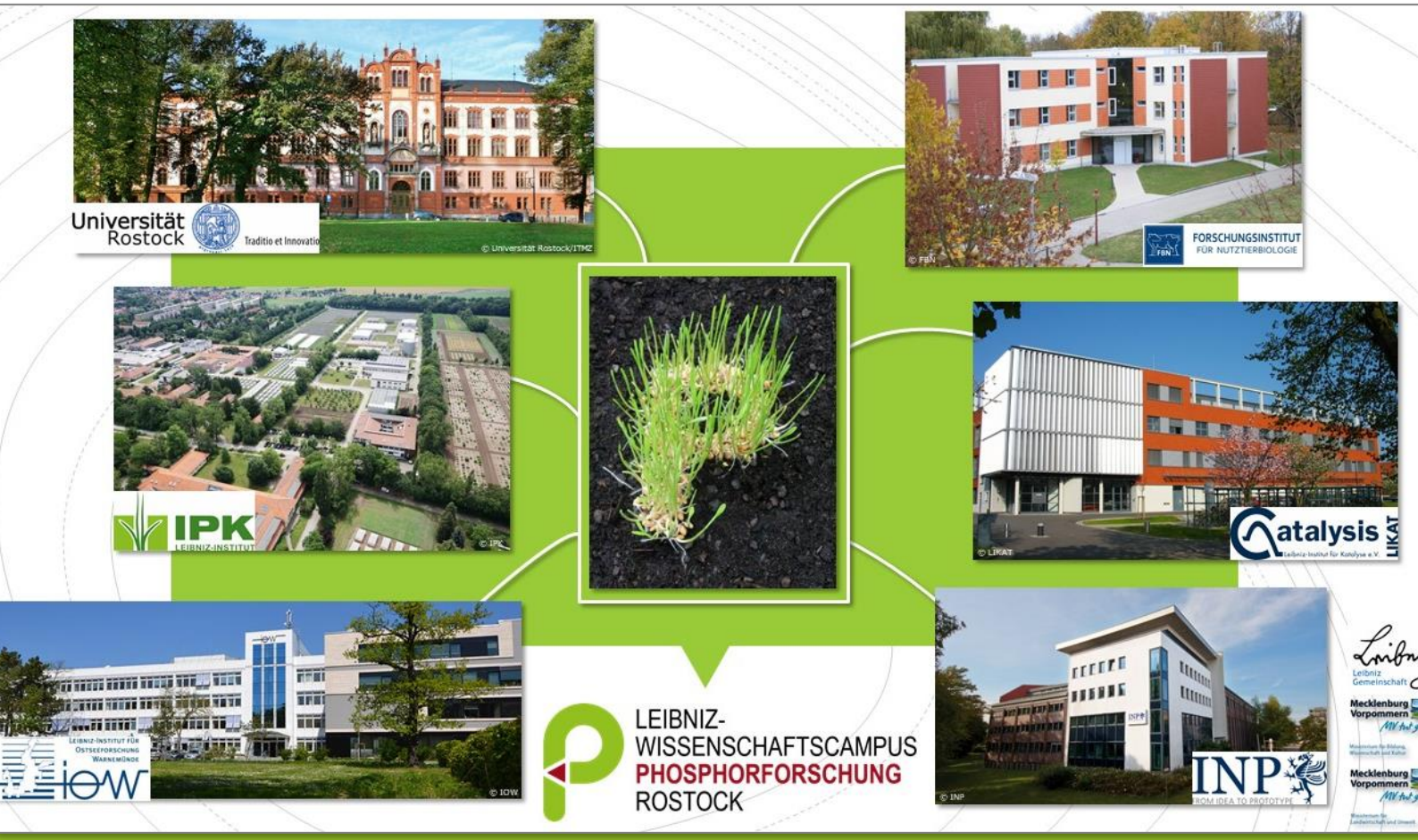
LEIBNIZ SCIENCE CAMPUS
PHOSPHORUS RESEARCH
ROSTOCK



Activity Report 2021

atalysis 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 2021) 98 scientists from six research institutes in different disciplines working in 20 third-party funded projects. It focuses on three main areas in the support of phosphorus research by its members: strengthening of **networking**, **internationalization** and funding of **graduate students**.

Although limited by the Corona pandemic, events of various formats were held in 2021 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 P-Breakfast, the P-Analytics workshop and the lecture series, 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.

Due to the visibility of the P-Campus research, the Coordination Office was contacted in 2020 and 2021 by a scientist from **ZALF** (Leibniz Centre for Agricultural Landscape Research, www.zalf.de/en/) and a scientist from the **Roman-Germanic Commission** of the German Archaeological Institute (www.dainst.org/en/). It was possible in both cases to successfully establish contact with several scientists in the P-Campus. Further details can be found in chapter 4 Networking.

The **Leibniz Innovation Farm for Sustainable Bioeconomy**, initiated by ATB (Leibniz Institute for Agricultural Engineering and Bioeconomy, www.atb-potsdam.de/en/), started in 2021 (www.atb-potsdam.de/en/news-and-press/). Members of the P-Campus (from UR, IOW, FBN) are involved in the project proposal development workshops that have been ongoing since 2021.

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 originally scheduled to take place in November 2021 but had to be rescheduled for January 6-7, 2022. The symposium was intended to be a hybrid event, but due to the Corona situation, it could only be conducted in an online format.

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. This allows PhD students to travel and present their findings in this way. This was not possible in 2021 as conferences were cancelled and research stays were not feasible as usual.

In spring 2021, the **18th European Workshop on Phosphorus Chemistry (EWPC 18)** was to take place in Rostock. Unfortunately, the on-site conference had to be cancelled; a very well-attended online conference was held instead. The EWPC 18 was postponed as

an attendance event until September 2022 (https://www.ewpc18.uni-rostock.de/). 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 such as thematic workshops, professional training and informal meetings. The start workshop 'P analytics' for the new PhD students of the P-Campus at the Biological Station Zingst in November (CW 48) 2019 was organized and co-supervised by the P-Campus coordinator. A second start workshop for the PhD students hired later, originally planned for summer 2020, could not be realized due to Corona restrictions neither in summer 2020 nor in summer 2021. Now, in the summer of 2022, a P analytics workshop is planned to take place as part of a one-week summer school. As already mentioned, an online lecture series was organised again in 2021 (Table 6). Ten of the twelve lectures were presented by P-Campus PhD students to give them an opportunity to present their work.

By March 2021, six PhD theses from PGS1 had been successfully defended. In summer 2021, the first PhD student of PGS2 successfully defended her PhD thesis.

In 2021, 20 **third-party funded projects**, which can be thematically assigned to the P-Campus, were running (Table 1).

To continue the successful concept of the **seed projects**, the first six seed projects have been granted as of June 2019. Most of the projects were completed in 2019. Due to Corona restrictions, two projects (P-Cat and ProCycle) had to be extended in a cost-neutral manner. The ProCycle project was successfully completed in 2020 and the P-Cat project until 31.12.2021. Project reports are available on request, except for P-Cat currently.

In 2021, three publications received the **P-Campus Publication Award** (see chapter 3.4 Publications).

The **public relations work** of the P-Campus included, besides text writing, publishing and presentations, also the maintenance of the website. Due to Corona restrictions, the "Long Night of the Sciences" at the University of Rostock, where normally the P-Campus would have presented current research topics to the public, could also not take place in presence in 2021.

In 2020, work continued on the **information video on research in the P-Campus**. In the process, many members of the P-Campus also provided input in the form of text blocks, photos and video recordings or other support for the subcontractor commissioned with the work. The video was completed in the first quarter of 2021 and can be freely accessed on the internet: either on the P-Campus YouTube channel (https://www.youtube.com/channel/UCP8Ms5exqY2v-gIcdodKYzw) or directly on the P-Campus website: https://wissenschaftscampus-rostock.de/about-us/goals-concept.html.

In September 2021, the **book "Phosphor – Fluch und Segen eines Elements"** (https://www.oekom.de/buch/phosphor-9783962382827) was published. Three book chapters were written by P-Campus members (P. Leinweber, C. Baum, A. Zacher: chapter 8 - Phosphor im System Boden – Pflanze – Gewässer; J. Tränckner: chapter 13 - Phosphorrückgewinnung und -recycling aus Abwasser; J. Stubenrauch: chapter 15 - Mögliche Wege der Phosphor-Governance). One copy was acquired by the library of the University of Rostock at the request of the P-Campus. Three books were purchased by the P-

Campus and can be borrowed in the library of the IOW or in the P-Campus coordination office.

The P-Campus will run until 30 November 2023, including a 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 Network 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 "Phosphorus in Agriculture, Environment and Nutrition: Ecological Consequences and Societal Challenges"** (working title) is to consist of four main research areas (I. P in agribusiness, II. P in the Environment, III. P in Nutrition and Medicine, IV. P-Resources, P-Governance) and one 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 "Regulatory mechanisms of phosphorus (P) homeostasis in biological systems along the P concentration gradients in the land-sea transition"** (working title) will consist of three research clusters: I. P metabolism in terrestrial organisms, II. P metabolism in the transition zone and III. P metabolism in aquatic organisms.

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. 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. 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 Warnemünde (IOW)
- 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 2a (for PGS 1) and 2b (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”, 23 publications (including five dissertations) were published. The following two publications can be highlighted in particular, as they emphasise the interdisciplinary cooperation in the P-Campus. The publication Wirth et al. arose from the seed project “AMPA” and was awarded the P-Campus publication prize in 2021. The institutions of the P-Campus members are inserted in brackets after their names.

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

Zocher, K., Gros, P. (UR, WG Soil Science), Werneburg, M., Brüser, V. (INP), Kolb, J.F., Leinweber, P. (UR, WG Soil Science) (2021) Degradation of glyphosate in water by the application of surface corona discharges. Water Sci Technol 84 (5), 1293-1301, DOI: 10.2166/wst.2021.320

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 2021, 21 publications were published in "Cluster II: Sufficiency and Efficiency of P Utilization, P Recycling". Due to their multidisciplinary collaboration, the following two publications can be highlighted:

Eichler-Löbermann, B. (UR, WG Agronomy), Zicker, T. (UR, WG Agronomy), Kavka, M. (UR, WG Agronomy), Busch, S., Brandt, C. (IPK), Stahn, P., Miegel, K. (2021) Mixed cropping of maize or sorghum with legumes as affected by long-term phosphorus management. Field Crops Research 265, 108120, DOI: 10.1016/j.fcr.2021.108120

Zacher, A. (UR, WG Soil Science), Baum, C. (UR, WG Soil Science), de Mol (UR, WG Crop Health), F., Dehmer, K.J. (IPK), Gerowitt, B. (UR, WG Crop Health) (2021) Mixed growth with weeds promotes mycorrhizal colonization and increases the plant-availability of phosphorus under maize (*Zea mays* L.). Agronomy 11, 1304, DOI: 10.3390/agronomy11071304

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, and the synthesis of antitumor compounds are addressed.

11 publications were published in "Cluster III: P in Synthesis and Catalysis". At this point, the following three publications can be highlighted. The first two reflect the interdisciplinary cooperation within the P-Campus. The publication Wirth et al. was a result of a collaboration between the IOW, LIKAT and the UR, WG Soil Science from the seed project AMPA and was awarded the P-Campus Publication Prize in 2021. The second publication could only be realized due to a close cooperation between the INP and the UR, WG Soil Science. The third publication is worthy of mention, as the use of a waste product (poly(methylhydrosiloxane)) enables the use of catalytic amounts of a phosphorus compound in a significant chemical reaction.

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

Zocher, K., Gros, P. (UR, WG Soil Science), Werneburg, M., Brüser, V. (INP), Kolb, J.F., Leinweber, P. (UR, WG Soil Science) (2021) Degradation of glyphosate in water by the application of surface corona discharges. Water Sci Technol 84 (5), 1293-1301, DOI: 10.2166/wst.2021.320

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

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).

16 publications could be assigned to "Cluster IV: Molecular Biology of P". Two of the publications in Cluster IV were selected for the P-Campus Publication Award 2021:

Oster, M. (FBN), Reyer, H., Gerlinger, C. (FBN), Trakooljul, N., Siengdee, P., Keiler, J. (UMR), Ponsuksili, S. (FBN), Wolf, P. (UR, WG Tierernährung), Wimmers, K. (FBN) (2021) mRNA profiles of porcine parathyroid glands following variable phosphorus supplies throughout fetal and postnatal life. Biomedicines 2021, 9, 454, DOI: 10.3390/biomedicines9050454

Sokolov, E. P. (IOW), Adzigbli, L. (FBN), Markert, S., Bundgaard, A., Fago, A., Becher, D., Hirschfeld, C., Sokolova, I. M. (UR, MNF) (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

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, eight publications were published in 2021. Particularly noteworthy are:

Garske, B., Ekardt, F. (2021) Economic policy instruments for sustainable phosphorus management: taking into account climate and biodiversity targets. Environ Sci Eur 33, 56, 1-20, DOI: 10.1186/s12302-021-00499-7

Garske, B., Bau, A., Ekardt, F. (2021) Digitalization and AI in European agriculture: A strategy for achieving climate and biodiversity targets? Sustainability 13, 4652, DOI: 10.3390/su13094652

On the one hand, an innovative approach of economic policy instruments for P as well as for an integrated solution of other agricultural-related environmental problems was developed. On the other hand, opportunities and limits of agricultural digitalization were analyzed with specific reference to P, combined with conclusions for the choice of the most effective policy instruments.

3.2 Research Projects

Within the research clusters, 20 disciplinary and interdisciplinary, third-party funded projects (including PGS 2) were thematically assigned to the P-Campus in 2021 (Table 1). Four of these projects started newly in 2021 and five projects ended in 2021.

Table 1. Third-party funded research projects thematically assigned to the P-Campus (status as of December 2021; *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
AC/DC-weeds: Applying and combining disturbance and competition for an agro-ecological management of creeping perennial weeds	*04/2019-03/2022*	*DFG*	*University of Rostock (AUF)*	*I*
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*
DiveCropS: Diversifying cropping systems - Traditional knowledge and innovative approaches	01/2019-12/2022	DAAD	University of Rostock	II
Graduate School II: Leibniz ScienceCampus Phosphorus Research Rostock	07/2019-06/2023	WGL	FBN, IOW, INP, IPK, LIKAT, University of Rostock	I, II, III, IV, V
InFertRes: Innovative Fertilizers and Resource Efficiency in Agriculture	03/2018–02/2021	BMBF	University of Rostock (AUF)	II
InnoSoilPhos II: Innovative solutions to sustainable soil phosphorus management	03/2018 – 02/2021	BMBF	University of Rostock (AUF)	I, II, Q
InnoSoilPhos III: Innovative solutions to sustainable soil phosphorus management	05/2021 – 04/2024	BMBF	University of Rostock (AUF)	I, II, Q
Kombination von Biokatalyse und Kristallisation für die Synthese chiraler Amine	*04/2019-03/2022*	*BMWi*	*University of Rostock (MNF)*	*III*
MitoBOX: The mitochondrial basis of hypoxia tolerance in marine mollusks	*02/2019-01/2022*	*DFG*	*University of Rostock (MNF)*	*IV*
PEGaSus: Phosphorus efficiency in Gallus gallus and Sus scrofa – Bridging the gaps in the phosphorus value chain	*09/2017-02/2021*	*EU (H2020)*	*FBN*	*II, IV*
P-FOWL: Characterizing endocrine and transcriptional determinants of P utilization mediated by the environment-host-microbiota interaction in laying hens and quails, sub-project in FOR 2601	06/2018 – 11/2021	DFG	FBN	IV
P-FOWL: Data integration to derive biological networks of host gut expression and microbiota variation related to inositol phosphates, myo-inositol and P utilization in laying hens and quails, sub-project in FOR 2601	10/2018 – 05/2022	DFG	FBN	IV
PNC-Processing: Stoffkreisoptimierung durch Fraktionierung von Gülle in Phosphor, Stickstoff und organischen Kohlenstoff	07/2019-12/2021	BMBF	University of Rostock (AUF)	II
**PROCESSOR: Phosphorus recycling from complex scarcely soluble societal resources – letting the soil do the work*	*2021-2024*		*University of Rostock (AUF)*	*II*

Project Name	Term	Sponsor	Participating Partners of the P-Campus	Cluster
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)	
Verbundvorhaben: Züchterische Verbesserung der Phosphor-Aneignungseffizienz von Stärkekartoffeln und eine ressourcenschonende Rohstoffproduktion; Teilvorhaben 1	03/2019-02/2022	BMEL	IPK	II
Verbundvorhaben: Züchterische Verbesserung der Phosphor-Aneignungseffizienz von Stärkekartoffeln und eine ressourcenschonende Rohstoffproduktion; Teilvorhaben 2	03/2019-02/2022	BMEL	University of Rostock (AUF)	II
Verbundvorhaben: Selektion und Züchtung nährstoffeffizienter, *Phytophthora*-resistenter Kartoffelzuchtstämmen für einen nachhaltigen ökologischen Landbau	03/2020-10/2022	BMEL	IPK	II
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
WETSCAPES: Stoffumsetzungsprozesse an Moor- und Küstenstandorten als Grundlage für Landnutzung, Klimawirkung und Gewässerschutz	*01/2017-12/2020*	*European Social Fund*	*University of Rostock (AUF)*	*I, II, Q*

* 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**), funded by the Leibniz Association (WGL), consisted of eleven sub-projects (Table 3a in chapter 3.3). Two PhD students dropped out due to personal reasons, the respective supervisors finished the projects. There were six dissertations successfully completed by the end of 2021. For the remaining three projects, the submission of the dissertation is still planned. The second P-Campus Graduate School (**PGS 2**) consists of 15 sub-projects (Table 3b in Chapter 3.3), which all started by October 2020. Project I.1 was newly tendered and staffed in 2021, as the original project manager passed away in the first half of 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 from June 2019. Most of the projects were completed in 2019; some of the projects were still running in 2020. Due to the Corona restrictions, there were some delays in the laboratory work, so that a cost-neutral extension was necessary for two projects (P-Cat and ProCycle). The ProCycle project was successfully completed in December 2020. The P-Cat project had to be extended until 31.12.2021 due to the Corona delays and could then be successfully completed. The respective short reports of the completed projects (green) can be provided upon request. The final report for P-Cat is expected by summer 2022.

Table 2. Seed projects of the P-Campus 2019, funded by WGL grant of the P-Campus and approved in July 2019 (projects with final report available in green)

Project	Participating Partners
Funding Period 2	
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) (07/2020-12/2021)	UR, LIKAT

Abbreviations: FBN= Research Institute for Farm Animal Biology, 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

In 2018, the P-Campus (PGS1) funded the **seed project "Crysphos - crystallization-based separation of organic phosphates"**. The basic aim of the seed project "Crysphos" was the crystallization of organic phosphates, which are especially relevant for the use within biocatalytic synthesis reactions. Despite the high price of some of these phosphates, the usual form of process control includes only a single use of these compounds, so that these catalysts are ultimately disposed of without being used. A few processes allow indirect (partial) reuse by recycling the reaction solution, but here, too, the remaining mother liquor, including the organic phosphates, is disposed of unused after 2-3 batch reactions. In order to enable a real reuse of these organocatalysts, the targeted crystallization of organic phosphates by means of metal ions from the lanthanide group was investigated, which should eventually enable a potential recycling. The experimental work clearly showed that near-quantitative separation is possible for almost all the organic phosphates studied, additionally taking advantage of the solubility differences between lanthanum and yttrium salts.

The project was so successful that it was not only presented at special conferences, but a patent was also applied for via the University of Rostock. The patent was successfully filed in November 2021. A publication and a DFG proposal on this are now in progress. The project report can now also be released, and a summary is available on the P-Campus website.

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.

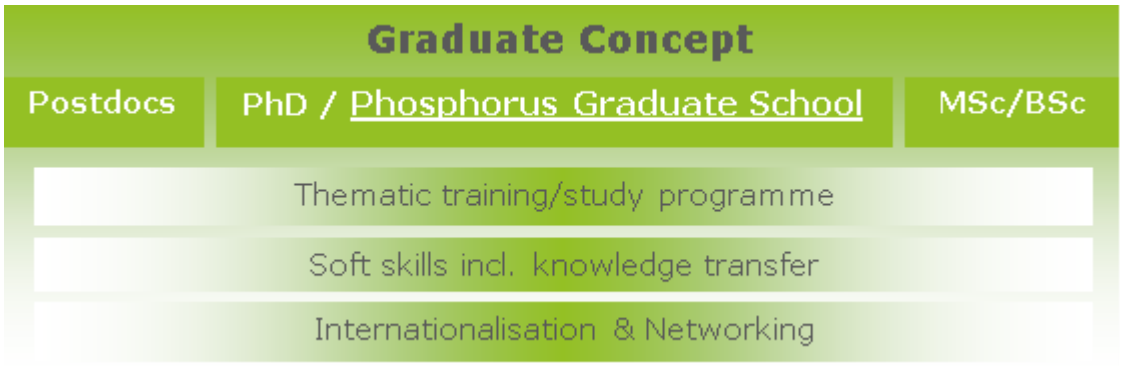


Figure 1. Graduate Concept of the Leibniz ScienceCampus Phosphorus Research Rostock

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, usually held in November. Lively exchanges of information between PhD students are promoted through various events, such as workshops and the regularly held P-Breakfast (could not take place since 2020). Positive support for these activities has come from opening the events to other PhD students with thesis topics in phosphorus-related research.

In the fourth quarter of 2019, a start workshop "P-Analytics" was successfully conducted with the first PhD students of PGS2 of the P-Campus. A second start workshop "P-Analytics" for PhD students hired only from 2020 (originally planned for summer 2020, then considered for 2021) at the Biological Station Zingst could not take place so far due to the Corona restrictions. This **P-Analytics workshop** is now planned as part of a summer school in 2022.
For the summer semester 2021 and the winter semester 2021/22 (May 2021 to the end of January 2022), a **lecture series** has also been organized by the coordination office of the P-Campus as a video colloquium with twelve lectures. The lecture series was, with 10 out of 12 lectures, almost completely presented by P-Campus PhD students to enable them to present their research results and to improve the scientific exchange (Table 6).

By the end of 2020, four PhD students of the first graduate school (PGS1) had successfully completed their dissertations and a fifth dissertation was submitted. The defense date scheduled for December 15, 2020, was postponed to February 2021 due to Corona and then the dissertation was successfully defended. The sixth dissertation was submitted in early January 2021 and successfully defended in March 2021. The successfully defended dissertations are listed in green font in Table 3a. The submission of the remaining three dissertations of PGS1 is still planned by the PhD students (marked in orange). 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).

Table 3a. Subprojects of the Graduate School 1 (PGS 1; 2015-2019, financed by the Leibniz Association) (green: dissertation fully completed, orange: dissertation still planned, red: dissertation discontinued, project terminated by supervisor)

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. One project had to be reworked with regard to the project objectives because the person working on it passed away in May 2020, and it had to be put out to tender again at the beginning of 2021. The position could be restaffed in 2021 as a PostDoc position with an adjusted project schedule. Project I.3 started in January 2020 with a PhD student who has already been working, with different funding, since October 2017 on the topic of detection of glyphosate and similar compounds in seawater. She was able to successfully contribute her previous experience and results to the project and defended her dissertation in the summer of 2021.
Since some PhD students did not start until third or fourth quarter 2020 (delays due to Corona restrictions), PGS 2 was cost-neutrally extended from May 2023 to November 2023.

Table 3b. Subprojects of the Graduate School 2 (PGS 2, 2019-2023, financed by the Leibniz Association), 2021 successfully defended dissertation in green

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

Project	Participating Partners	Research Focus
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
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

Due to Corona restrictions, some PGS2 PhD projects were not able to carry out their research in 2020 and 2021 as planned, resulting in time delays. In the first quarter of 2021, the coordination office successfully took care of forwarding the application to the WGL for corresponding corona aid for project II.3 P-Legumes. During 2021, the application and approval of a P-Campus internal funding for the projects IV.1 Soil Crusts and IV.3 Cyanoblooms (project extension by four and six months respectively) was also organized.

A **Winter School** "Scientific Writing and Successful Publishing" was in preparation for February 2022. This event is to be held as an on-site event over 4 days (https://wissenschaftscampus-rostock.de/winter-school-2022.html). As the Winter School is to be held as a compulsory face-to-face event, it has been postponed to the 12th week of 2022 (March) due to the pandemic circumstances.

Two additional **Summer Schools**, each lasting one week, are planned to take place between May and September 2022. In the summer/fall of 2021, members and institutes of the P-Campus have agreed to provide rooms for this summer school or scientists have agreed to organize the corresponding lectures/seminars. Although in 2020 and 2021 face-to-face teaching was severely limited, some PhD students had the opportunity to **co-supervise** students for their term papers or final theses (BSc, MSc) and thus gained valuable **teaching experience**.

3.4 Publications

The following three publications were honored with the **Publication Award 2021** because authors from at least two partner institutions were involved in the peer-reviewed key publications (P-Campus members in **bold**, (former) PhD students also in ***italics***):

Oster, M., Reyer, H., ***Gerlinger, C.***, Trakooljul, N., Siengdee, P., **Keiler, J.**, Ponsuksili, S., **Wolf, P.**, **Wimmers, K.** (2021) mRNA Profiles of Porcine Parathyroid Glands Following Variable Phosphorus Supplies throughout Fetal and Postnatal Life. Biomedicines 2021, 9, 454, DOI: 10.3390/biomedicines9050454

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

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

In the following, all publications from phosphorus research of the members of the P-Campus from the year 2021 are listed here.

Amorim, K., Piontkivska, H., Zettler, M. L., Sokolov, E., Hinzke, T., Nair, A. M., Sokolova, I. M. (2021) Transcriptional response of key metabolic and stress response genes of a nuculanid bivalve, *Lembulus bicuspidatus* from an oxygen minimum zone exposed to hypoxia-reoxygenation. Comparative Biochemistry and Physiology, Part B: Biochemistry and Molecular Biology 256, 110617, DOI: 10.1016/j.cbpb.2021.110617

Angello, Z.A., Behailu, B. M., Tränckner, J. (2021) Selection of optimum pollution load reduction and water quality improvement approaches using scenario based water quality modeling in Little Akaki River, Ethiopia. Water, 13 (5), 584, 1-22, DOI: 10.3390/w13050584

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Baumann, K., Eckhardt, K.-U., Acksel, A., Gros, P., Glaser, K., Gillespie, A.W., Karsten, U., Leinweber, P. (2021) Contribution of biological soil crusts to soil organic matter composition and stability in temperate forests. Soil Biology and Biochemistry 160, DOI: 10.1016/j.soilbio.2021.108315

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Eichler-Löbermann, B., Zicker, T., Kavka, M., Busch, S., Brandt, C., Stahn, P., Miegel, K. (2021) Mixed cropping of maize or sorghum with legumes as affected by long-term phosphorus management. Field Crops Research 265, 1-10, 108120, DOI: 10.1016/j.fcr.2021.108120

Fischer, M., Hering-Junghans, C. (2021) On 1,3-phosphaazaallenes and their diverse reactivity. Chem. Sci. 12, 10279, DOI: 10.1039/d1sc02947a

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Garske, B., Bau, A., Ekardt, F. (2021) Digitalisierung und KI in der europäischen Landwirtschaft: Strategie zur Erreichung der Klima- und Biodiversitätsziele? Natur und Recht 43, 445-455, DOI: 10.1007/s10357-021-3867-6

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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, DOI: 10.1016/j.chemosphere.2020.128327

Wu, F., Sokolov, E. P., Dellwig, O., Sokolova, I. M. (2021) Season-dependent effects of ZnO nanoparticles and elevated temperature on bioenergetics of the blue mussel *Mytilus edulis*. Chemosphere 263, 127780, 1-13, DOI: 10.1016/j.chemosphere.2020.127780

Zacher, A., Baum, C., de Mol, F., Dehmer, K.J., Gerowitt, B. (2021) Mixed growth with weeds promotes mycorrhizal colonization and increases the plant-availability of phosphorus under maize (*Zea mays* L.). Agronomy 11, 1304, DOI: 10.3390/agronomy11071304

Zerssa, G., Feyssa, D., Kim, D.-G., Eichler-Löbermann, B. (2021) Challenges of small-holder farming in Ethiopia and opportunities by adopting climate smart agriculture: A review. Agriculture 11, 192, 1-25, DOI: 10.3390/agriculture11030192

Zerssa, G., Kim, D.G., Koal, P., Eichler-Löbermann, B. (2021) Combination of compost and mineral fertilizers as an option for enhancing maize (*Zea mays* L.) yields and mitigating greenhouse gas emissions from a Nitisol in Ethiopia. Agronomy 11, 2097, 1-21, DOI: 10.3390/agronomy11112097

Zocher, K., Gros, P., Werneburg, M., Brüser, V., Kolb, J.F., Leinweber, P. (2021) Degradation of glyphosate in water by the application of surface corona discharges. Water Sci Technol 84 (5), 1293-1301, DOI: 10.2166/wst.2021.320

3.5 Theses

In 2021, four P-Campus members completed their dissertations (Table 4, *italics*). In addition, two further dissertations were supervised by P-Campus members. P-Campus members also supervised eight master's and five bachelor's theses. The bachelor theses were co-supervised by PhD students from PGS2.

Table 4. List of theses in the P-Campus

Thesis	Institution
Dissertations	
Chojetzki, L. (2021) Untersuchungen an neuartigen Derivaten des Singulett-Biradikals $[P(\mu\text{-NTer})]_2$.	UR-MNF
Habedank, F. (2021) Pflanzenschutzmittel als Phosphorquelle in der aquatischen Umwelt.	UR-MNF
Lohrer, C. (2021) Organische Phosphorverbindungen im deutschen Ostseeküstengebiet - Methodenentwicklung und Analyse. Dissertation PGS1	IOW, UR-MNF
Rönspieß, L. (2021) Estuarine phosphorus transformation, retention and bioavailability - An example from a eutrophic estuary in the southern Baltic Sea.	IOW, UR-MNF
Schaub, I. (2021) Die alkaline Phosphataseaktivität: ein Indikator für den Phosphorstatus in Phytoplanktongemeinschaften? Dissertation PGS1	UR-MNF
Wirth, M.A. (2021) Analysis of the herbicide glyphosate and related organophosphonates in seawater: Overcoming salt-matrix-induced limitations. Dissertation, PGS2	IOW, UR-MNF
Master Theses	
Díaz Lamprea, K. A. (2021) Phosphor-Dünger aus Klärschlamm-Biokohle	UR-AUF-SSC
Kühnemann, K. (2021) Phosphatase-Aktivität im Boden unter dem Einfluss verschiedener Genotypen von Luzerne und Rotklee	UR-AUF-AGR
Kühnreich, S. (2021) Wurzelmorphologie von Rotklee und Luzernen Accessionen in Abhängigkeit von der Phosphorversorgung	UR-AUF-AGR
Meyer, F. (2021) Phosphordüngewirkung von Biomasseaschen in Kombination mit verschiedenen Fruchtarten im Gefäßversuch	UR-AUF-AGR

Thesis	Institution
Müller, J. (2021) Bioverfügbarkeit von Phosphor im Boden bei langjähriger Gärrestdüngung	UR-AUF-AGR
Paap, V. (2021) Spezifität von Phosphatasen der Kartoffel gegenüber verschiedenen organischen Phosphorverbindungen	UR-AUF-AGR
Reese, D. (2021) P-Verfügbarkeit im Ober- und Unterboden beeinflusst durch den Anbau von Rotklee- und Luzernegenotypen	UR-AUF-AGR
Thiem, R. (2021) Einfluss von Luzerne- und Rotkleegenotypen auf die Pflanzenverfügbarkeit von Phosphor im Boden unter dem Einfluss von langjährigen Phosphordüngerstrategien	UR-AUF-AGR
Bachelor Theses	
Cedeno, L.A.Z. (2021) Auswirkungen der Phosphorverhältnisse in dem Boden durch Anbau von Rotklee und Luzerne Genotypen	UR-AUF-AGR
Dragunsky, L. (2021) Phosphorverfügbarkeit in biologischen Bodenkrusten auf Sanddünen verschiedener Sukzessionsstadien.	UR-MNF
Helm, K.G. (2021) Einfluss von Rotklee- und Luzernegenotypen auf den Gehalt an wasserlöslichem Phosphor im Boden im Dauerdüngungsversuch Rostock	UR-AUF-AGR
Reichel, P. (2021) Auswirkungen der Düngemaßnahmen auf N_{min}-Gehalt im Boden in Abhängigkeit von angebauten Klee und Luzerne Genotypen.	UR-AUF-AGR
Tornier, J.A. (2021) Nutzung von Mikrogranulaten und Mikroorganismen zur Stickstoff- und Phosphorversorgung im Maisanbau	UR-AUF-AGR

Abbreviations: AGR = chair of Agronomy, AUF = Faculty of Agricultural and Environmental Sciences, IOW = Leibniz Institute for Baltic Sea Research Warnemünde, 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 annual forum (09.09.2021, Dr. D. Zimmer), online

European Phosphorus Platform (ESPP) - Participation in the ESPP-organised online conference 4th Phosphorus in Europe Research Meeting (PERM) on 02.06.2021 (Dr. D. Zimmer), as well as three presentations by PhD students of the P-Campus on their projects:

Jonathan Schleyken "Project II.1 P recycling in animal husbandry"

Seyed Mohammadmahdi Seyedalmoosavi "Project II.2 Efficiency of recovered phosphorus for monogastric animals"

Yue Hu "Project II.3 P efficiency of forage legumes and their capacity to utilize P from recycling products"

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, Ass. Prof. Dr. Jakob Magid, Ass. Prof. Dr. Dorette Sophie Müller-Stöver)

New collaborations in the P-Campus:

Due to the visibility of the P-Campus research, the Coordination Office was contacted in 2020 and 2021 by a scientist from ZALF (Leibniz Centre for Agricultural Landscape Research, www.zalf.de/en/) and a scientist from the Roman-Germanic Commission of the German Archaeological Institute (www.dainst.org/en/). It was possible in both cases to successfully establish contact with several scientists in the P-Campus.

In cooperation with ZALF, a **concept for a third-party funded project** was developed in 2020 and 2021, in which the mutual influence of the (bio)availability of **Si and P** from the soil via groundwater to surface waters (limnic and marine) will be investigated. In addition to ZALF, the University of Rostock and IOW, the IGB (Leibniz Institute of Freshwater Ecology and Inland Fisheries: https://www.igb-berlin.de/en) is also involved in the intended cooperation. The project application has been largely prepared and is expected to be submitted to the BMBF in the next few months.

A **research collaboration** is being sought with scientists from the Roman-Germanic Commission to evaluate **soil phosphorus** and **vegetation** in the context of **archaeological research**. For this purpose, two student research projects started in the winter semester 2021/22, one with the WG Soil Science, the other with the WG Landscape Ecology at the Faculty of Agricultural and Environmental Sciences of the University of Rostock. If these projects are successful, they will serve as the basis for applications for third-party funding.

The **Leibniz Innovation Farm for Sustainable Bioeconomy**, initiated by the ATB (Leibniz Institute of Agricultural Engineering and Bioeconomy, https://www.atb-potsdam.de/en/), started in 2021 (https://www.atb-potsdam.de/en/news-and-press/). Members of the P-Campus (from UR, IOW, FBN, and from the Sustainability and Climate Policy Research Unit) are involved in the workshops (animal husbandry, agronomy, systems analysis) that have been ongoing since 2021 for the development of project proposals.

P. Leinweber (UR, WG Soil Science) is working as an external consultant in the **PROCESSOR project** at the University of Copenhagen, Department of Plant and Environmental Sciences. This advisory work includes participation in the planning of the experiments and in the selection of scientific personnel. Furthermore, soil material from northern Germany is provided for experiments and access to methods and laboratory capacity in Rostock is made possible. In addition, synchrotron-based investigations will also be planned and carried out jointly, and last but not least, a large number of joint publications will result from this.

Interdisciplinary collaboration between partners in the P-Campus

In the seed project "AMPA - Synthesis of isotope-labeled AMPA for the qualitative and quantitative analysis of glyphosate degradation in soil", which started in spring 2019 (PGS1), LIKAT worked together with colleagues from the IOW for the synthesis of isotope-labeled AMPA in the field of instrumental analysis in cooperation with the working group Soil Science (UR). This collaboration resulted in an interdisciplinary, partnership publication in 2021: 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. The open access costs of this publication were funded proportionally by the P-Campus (1,800 €) and the IOW (1,000 €).

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 2021** of the Leibniz Science Campus Phosphorus Research Rostock had to be postponed from November 2021 to January 2022 and took place as an online conference. Despite all the Corona-related restrictions, the research results as well as the networking and cooperation in the P-Campus could be demonstrated via several lectures and posters. 13 of the 24 presentations were given by PhD students from the P-Campus. Representatives of the International Scientific Advisory Council (SAC) of the P-Campus were also present at the symposium. The impressions of the SAC can be found in the appendix of the report.

Table 5. Presentations at the International P-Campus Symposium 2021 on 6/7 January 2022 (presentations by P-Campus PhD students in green)

Name of the speaker	Presentation	Cluster
Oral presentations		
Ashour A. Ahmed	Advance in understanding the P binding in soil	I
Christel Baum	Biofertilizer for an improved P mobilization in arable soils: potentials and limitations	I, II
Mareike Kavka	Intra- and extracellular phosphatase activities of P starved potato	II
Mousumi Hazarika	Phenotypic and genotypic screening of potato cultivars for phosphorus efficiency	II
Yue Hu	Project II.3: Phosphorus utilisation capacity of forage legumes from recycling products	II
Jens Tränckner (in Vertretung für J. Schleyken)	Project II.1: Recovery of concentrated P-products from animal excrements in husbandry and aquaculture	II
Bärbel Gerowitt	Measuring On-Farm Phosphorus Fertiliser Use—Lessons Learned From Surveying Data in Northern Germany	II
Kristin Steinfurth	Conversion equations between Olsen-P and other methods used to assess plant available soil phosphorus in Europe	II
Jan-Erik Siewert	Project III.1: Phosphine-catalysed Reduction of Dihalophosphanes	III
Constanza Terazzi	Project III.2 Application of P-based Organocatalysts and Biocatalysts for the Kinetic Resolution of Racemic Carbonates P-RaceCar	III
Jan Tönjes	Project III.3: The Catalytic Appel Reaction: Stereospecific Chlorination of Alcohols by P(III)/P(V) Redox Cycle Catalysis	III
Changyue Ren	Selective phosphonium salts catalysed N-methylation and N-formylation of amines with CO_2	III
Dagmar-Christiane Fischer	Orthotopic and ectopic mineralization: Two sites of a coin	IV
Maruf Hasan	Project IV.5 Tissue-wide expression of genes related to vitamin D metabolism and FGF23 signaling following variable phosphorus intake in pig	IV
Michael Oster	Inositol phosphates and myo-inositol in the domestic fowl: Exploring the interface of genetics, physiology, microbiology and nutrition	IV
Felix Ekardt	Phosphorus Justice: The Climate Verdict of the German Federal Constitutional Court and its Implications for Land Use	V
Katharine Heyl	Projects V. The Common Agricultural Policy and Phosphorus	V
Posters		
Karen Baumann	Redox induced mobilization of phosphorus in arable soils	I
Stefan Koch	Legacy Phosphorus in Sediments of Lowland Waterways	I

Name of the speaker	Presentation	Cluster
Julia Prüter	Influence of sample pretreatment on P speciation in sediments evaluated with sequential fractionation and P *K*-edge XANES spectroscopy	I
Rebekka Erlinghagen	Phenotyping Phosphorus and Nitrogen Efficiency in 40 Pre-Breeding Clones of Potato (*Solanum tuberosum* L.)	II
Jan von Langermann	Development of a Recovery Concept for Phosphate-based Cofactors from Aqueous Media	III
Sandra Kammann	P-Limitation in biological soil crusts of the Baltic Sea	IV
Mariano Santoro	How does Phosphorus availability influence cyanobacterial blooms in the Baltic Sea?	IV
Linda Adzigbli	Tissue and substrate-dependent mitochondrial responses to acute hypoxia-reoxygenation stress in a marine bivalve *Crassostrea gigas* (Thunberg, 1793)	IV

The **P-Campus Lecture Series** was again held online in the summer semester 2021 and winter semester 2021/22 (May 2021 to January 2022) (Table 6). This again resulted in a higher number of participants and the participation of more external interested parties, as no travel was necessary as in the previous on-site events. Ten of the twelve lectures were presented by PhD students from the P-Campus. Between 5 and 35 people attended the lectures. Between 28% and 59% of the participants were members of the P-Campus and the remaining participants were external interested parties.

Table 6. Topics, lecturers and participants of the der lecture series from May 2021 to January 2022 (lectures of PhD students are marked green)

Date	Topic	Lecturer	NP[a]
20.05.2021	I.2 Phosphor entlang seiner Transportwege – von terrestrischen in aquatische Ökosysteme	Julia Prüter (UR, Soil Science)	29
03.06.2021	Der Leibniz-Innovationshof	Prof. Ulrich Bathmann (IOW)	35
17.06.2021	IV.1 Vegetationskundliche Aufnahmen biologischer Bodenkrusten und ihr potentieller Einfluss auf die P-Dynamiken in den Sanddünen der Ostsee	Sandra Kammann (UR, Applied Ecol. & Phycol.)	17
01.07.2021	P-based organocatalysts: The application in CO_2 valorization and its immobilization with plasma techniques	Dr. Yuya Hu (LIKAT)	8
16.09.2021	II.1 P-Recycling in landgestützten Aquakultursystemen	Jonathan Schleyken (UR, Water Ma.)	16
14.10.2021	IV.3 P in marine microlife: a (cyano)bacterial perspective	Mariano Santoro (IOW)	21
11.11.2021	V. Agrarsubventionen der EU und P	Katharine Heyl (FNK)	10
25.11.2021	II.3 P utilisation capacity of forage legumes from recycling products	Yue Hu (UR, Pflanzenbau)	16
02.12.2021	II.2 Black Soldier Fly Larvae reared on recycled phosphorus-rich substrates as a feed component for broilers	Seyed Mohammad Mahdi Seyedalmoosavi (FBN)	6
16.12.2021	III.2 Application of P-based organocatalysts and biocatalysts	Constanza Terazzi (LIKAT)	5
13.01.2022	IV.3 Phenotypic and genotypic variability of P-uptake mechanisms in potato	Julian Kirchgesser (UR, Agronomy)	10
20.01.2022	N and P efficiency mechanisms in potato	Rebekka Erlinghagen (IPK)	12

[a] Notice: The number of participants (NP) is the number of people registered for the webinar, not those who actually attended. It was observed that there were always a few people less present at the events.

In spring 2021, the **18th European Workshop on Phosphorus Chemistry (EWPC 18)** should take place in Rostock. The EWPC was started to be organized in 2020 by members of LIKAT, the Institute of Chemistry of the University of Rostock and the coordination office of the P-Campus. The EWPC is a very important conference in phosphorus chemistry especially for young scientists and would have been a great opportunity to present the research location Rostock. Unfortunately, the on-site conference had to be cancelled; a very well-attended online conference was held instead. EWPC 18 has been postponed to September 2022 as an on-site conference (https://www.ewpc18.uni-rostock.de/). The organization will be done by the same organizing committee as originally.

On 22 April 2021, the **International Stakeholder Webinar** on "**Phosphorus in Agriculture**" organized by FBN took place. At the end of the funding period of the EU project "PEGaSus", a stakeholder webinar was organized for which 140 participants from 25 countries were registered. Current research results on feeding strategies, animal physiology and genetics, soil ecosystems, reuse and recycling options, economic value creation, legal aspects of manure management and policy instruments were presented around the topic of P and discussed with an interdisciplinary group of participants.

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 graduate/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 three months to discuss overarching issues as well as the strategic orientation and further development of the P-Campus. In 2021, some of the meetings took place online and others were possible in person (PE). In addition, meetings of selected members of the steering group (+ partly other scientists) took place for the concept development of a DFG Research Training Group and a Leibniz Research Alliance.

Meetings of the **steering group** of the P-Campus: 22.03.; 07.06.; 03.09.; 05.11. (PE); 14.12.

Meeting for **DFG Research Training Group** "P-Metabolism in Land-Sea Gradients": 02.08.; 30.08. (PE); 18.10. (PE); 06.12.

Meeting for the **Leibniz Research Alliance** "Phosphorus in Food, Environment, Economy: Ecological Consequences and Societal Challenges": 17.08.; 21.10. (PE); 13.12.

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)

63. Annual Meeting of the Society for Crop Science, 28 – 30.09.2021, online

Baum, C., Peine, M., Vitow, N., Zacher, A., Eichler-Löbermann, B., Leinweber, P. Düngungseinflüsse auf die funktionelle Diversität des Bodenmikrobioms.

Kavka, M., Kirchgesser, J., Hazarika, M., Korn, K., Paap, V., Bachmann-Pfabe, S., Dehmer, K.J., Uptmoor, R. Kartoffelpflanzen unter Phosphormangel – eine Untersuchung der Wurzelsysteme und Phosphataseaktivitäten.

Further presentations

Eichler-Löbermann, B. Agronomische Effekte von Biomasse-Aschen in Kombination mit unterschiedlichen Fruchtarten. Oral discussion FNR, June 2021.

Hazarika, M. Screening of potato genetic resources for phosphorus stress tolerance. EUCARPIA General Congress, online, 23-26.08.2021

Heyl, K., Göring, T., Garske, B., Stubenrauch, J., Ekardt, F. Sustainable phosphorus management under the future common agricultural policy: common agricultural policy, phosphorus, soil management, Paris Agreement, convention on biological diversity. 1st International Conference on Sustainable Resource Society, online, 25-26.10.2021

Hu, Y. Phosphorus utilisation capacity of forage legumes from recycling products. EUCARPIA-Section Fodder Crops and Amenity Grasses Meeting, online, 06-08.09.2021

Kavka, M. Nachhaltiger Umgang mit der endlichen Ressource Phosphor durch effiziente Kulturpflanzen. Lecture Series AgriCoast, online, 18.01.2021

Seyedalmoosavi, M.M., Daş, G., Metges, C.C. Influence of different amounts of black soldier fly larvae (BSFL) in the ration on nutrient and energy utilization and growth of broilers. 75th Digital Conference of the Society of Nutrition Physiology, online, 16-18.03.2021

Tränckner, J. P-Strategie Mecklenburg-Vorpommern. DWA Web-Forum "Phosphorrecycling - Strategien und Lösungsansätze", online, 04.02.2021

Other Events

On December 8, 2021, the **year-end meeting** between members of the P-Campus and representatives of the Ministry of Agriculture and the Ministry of Education of MV took place. In addition to the presentation on the general development and future of the P-Campus, three projects were presented by P-Campus members (presenters underlined):

Zimmer, D., Wimmers, K. Der Leibniz-WissenschaftsCampus Phosphorforschung Rostock 2021

PhD project: II.2 Rearing of black soldier fly larvae (BSFL) on recycled phosphorus-rich substrates and their use as a component of broiler feeds. (Mohammad Mahdi Seyedalmoosavi, Dr. Gürbüz Daş, Prof. Petra Wolf, Prof. Cornelia Christiane Metges, Prof. Jens Tränckner, Prof. Klaus Wimmers (FBN; Chair of Nutritional Physiology and Animal Nutrition, Chair of Water Management, University of Rostock)

Seed project: synthesis of isotope-labeled AMPA and glyphosate detection in the Baltic Sea. (Dr. Marion Kanwischer, Dr. Thomas Werner, Prof. Peter Leinweber (IOW; LIKAT; Chair of Soil Science, University of Rostock)

The P-starch project: improving phosphorus efficiency in starch potatoes. (Julian Kirchgesser, Prof. Ralf Uptmoor, Dr. Silvia Bachmann-Pfabe, Mousumi Hazarika (Chair of Agronomy, University of Rostock; IPK)

6.2 Posters (Selection)

4th Phosphorus in Europe Research Meeting (PERM), 02.06.2021, online

Hu, Y., Dehmer, K.J., Eichler-Löbermann, B. P utilisation capacity of forage legumes from recycling products.

Schleyken, J., Tränckner, J., Palm, H. Aquaculture-applied phosphorus recycling in animal husbandry.

Seyedalmoosavi, S.M.M., Das, G., Mielenz, M., Metges, C.C. Black Soldier Fly larvae reared on feed mixed with recycled sewage sludge accumulate Ca and P.

63. Annual Meeting of the Society for Crop Science, 27 – 30.09.2021, Rostock

Hu, Y., Dehmer, K.J., Willner, E., Bachmann-Pfabe, S., Eichler-Löbermann, B. P utilisation capacity of forage legumes from recycling products. Closing the cycle - Pflanze und Tier im Agrarsystem.

Kirchgesser, J., Kavka, M., Hazarika, M., Bachmann-Pfabe, S., Dehmer, K.J., Uptmoor, R. Genotype and P-dependent variability of root-system architecture in potato (Solanum tuberosum L.).

Müller, J., Liermann, R., Mahnke, B., Dittmann, L. Effekte unterschiedlicher P-Dünger auf den Futterwert von Kleegrasgemengen.

Tropentag 2021, 15 – 17.09.2021, Hohenheim/online

Bullaín, M., López, R., Fall, F., Eichler Löbermann, B., Pruneau, L., Bâ, AM. Ectomycorrhizal fungus Scleroderma bermudense for improve the salt tolerance in Coccoloba uvifera (L.).

Fundora, O., De La Fé, P., Rodríguez, K., Gálvez, G., Eichler-Löbermann, B. Plant Promoting or inhibiting effect of sugarcane ashes applied with mycorrhizal fungi to Cuban soils.

Vento, R., Días, V., Cabrera, E., Pérez, E., Eichler-Löbermann, B. Twenty years of agroecological practices on a family farm in Pinar del Río, Cuba.

Further posters

López, R., Eichler-Löbermann, B., Vigoa, Y., Gomes, E., Rodríguez, L. Phenotypic plasticity and response to saline stress of seven pasture legumes. First international congress in biotechnology and neotropical ecosystems. CIBEN - 1st international congress in biotechnology and neotropical ecosystems, online, 20.-22.10.2021

Terazzi, C., Werner, T., von Langermann, J. Pig Liver Esterase-Catalyzed Kinetic Resolution of Cyclic Carbonates. Biotrans 2021, Graz, Austria/online, 19.-22.07.2021

Tönjes, J., Longwitz, L., Werner, T. Poly(methylhydrosiloxane) as a Green Reductant in the Catalytic Base-Free Wittig Reaction via PIII/PV Catalysis. Online Workshop on Phosphorus Chemistry (OWPC 2021), online, 29.-31.03.2021

6.3 Press

Neuer Recyclingdünger aus Rostock - Article on vdi-nachrichten.com, 21.06.2021
Rostocker Forscher entwickeln neuen Recycling-Dünger - Article on idw-pnline.de, 21.06.2021
Rostocker Forscher entwickeln neuen Recycling-Dünger - Article on innovations-report.de, 21.06.2021
Rostocker Forscher entwickeln neuen Dünger - Article in newspaper Ostsee-Zeitung, p. 12, 30.06.2021

6.4 Websites

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

Project website **PEGaSus** - **P**hosphorus **e**fficiency in **Ga**llus gallus and **Sus** scrofa – Bridging the gaps in the phosphorus value chain: www.pegasus.fbn-dummerstorf.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**. Direct **coordination** is carried out by a staff scientist, supported by a secretary. 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 20 PhD students from 40 Working Groups are **Members** (see Partners and Members) of the P-Campus.

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

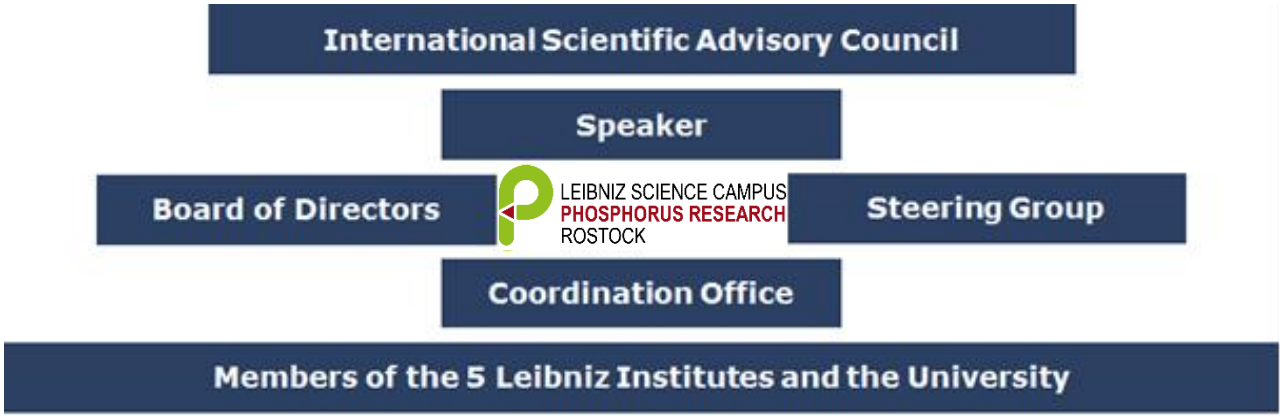

Figure 4. Structure of the Leibniz ScienceCampus Phosphorus Research Rostock

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. Ulrich Bathmann, IOW
Prof. Dr. Matthias Beller, LIKAT
Prof. Dr. Andreas Graner, IPK
Prof. Dr. Wolfgang Schareck, UR
Prof. Dr. Klaus-Dieter Weltmann, INP
Prof. Dr. Klaus Wimmers, FBN

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
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7.2.5 Coordination Office

(Work and tasks 2021: see Appendix)
Dr. Dana Zimmer (Coordinator)
Maxi Hoche (Secretary)

7.2.6 Members

(Status: Updated during 2021)

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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
Prof. Dr. Uwe Rosenthal	Coordination Chemistry and Catalysis	Cluster III
Jan-Erik Siewert	Activation of small molecules	Cluster III
Constanza Terazzi	Organocatalysis	Cluster III
Jan Tönjes	Organocatalysis	Cluster III
PD Dr. Thomas Werner	Organocatalysis	Cluster III

Research Institute for Farm Animal Biology (FBN), Dummerstorf

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Christian Gerlinger	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 Almoosavi	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

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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

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Dr. Christine Brandt	Genebank, Satellite Collections North	Cluster II
Dr. Klaus Dehmer	Genebank, Satellite Collections North	Cluster II
Rebekka Erlinghagen	Genebank, Satellite Collections North	Cluster II
Prof. Dr. Andreas Graner	Director	Cluster II
Mousumi Hazarika	Genebank, Satellite Collections North	Cluster II
Yue Hu	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

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PD Dr. Christel Baum	Soil Science	Cluster II
Dr. Karen Baumann	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
Michael Cramer	Water Resources Management	Cluster II
Dr. Carsten Croonenbroeck	Agricultural Economics	Cluster II
apl. Prof. Dr. Bettina Eichler-Löbermann	Agronomy	Cluster II
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
Katharina Heyl	Research Unit Sustainability and Climate Policy	Cluster V
Prof. Dr. Florian Jansen	Landscape Ecology and Site Evaluation	Cluster I
Dr. Mareike Kavka	Agronomy	Cluster II
Julian Kirchgesser	Agronomy	Cluster II
Dipl. Agr.-Ing. Ulrich Knaus	Aquaculture and Sea-Ranching	Cluster I, II
Philipp Koal	Agronomy	Cluster 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
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Faculty of Law

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Faculty of Mathematics and Natural Sciences

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Maximilian Berthold	Institute for Biological Sciences, Applied Ecology & Phycology	Cluster I, Q
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PD Dr. Stefan Forster	Institute for Biological Sciences, Marine Biology	Cluster I
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Prof. Dr. Martin Hagemann	Institute for Biological Sciences, Animal Physiol-ogy	Cluster II
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Dr. Jan von Langermann	Institute for Chemistry, Biocatalysis	Cluster III

Rostock University Medical Center		
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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. 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
Ass. Prof. Dr. Jakob Magid
Ass. Prof. Dr. Dorette Sophie Müller-Stöver

8 Funding

In 2021, the P-Campus was funded by the Ministry of Education Mecklenburg-Vorpommern, by the Leibniz Association and by substantial 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).

Funds from the Ministry of Education Mecklenburg-Vorpommern (about € 132,000 in 2021) were used mainly to finance the Coordination Office of the P-Campus. 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.

APPENDIX

Contents

Impressions of the Scientific Advisory Council, January 7th, 2022

The Leibniz Science Campus for Phosphorus Research is an inspiring and shining example - not only in Germany, but internationally - of the benefits of integrated cross-disciplinary research and graduate training. This unique facility brings together research expertise from the University of Rostock and the 5 Leibniz Institutes, all focused around a pressing scientific theme of central importance to society: phosphorus. Our health, wellbeing and environment depends upon the continuing availability and judicious use this amazing element.

It is always a pleasure to hear from the enthusiastic P-Campus members about their research at the annual symposium. Indeed, there is no other forum where we have the opportunity to learn about such a diversity of P-related research, for example:

Phosphorus utilisation efficiency in crop production: we heard on day 1 of the P-Campus Symposium research highlights about phenotypic and genotypic screening of potato cultivars; and the importance of phosphatase activity not only in roots, but in old leaves of P-deficient potato plants for recycling P compounds into the growing biomass.

Not all recycled P products are equal: we have learned how organic fertilisers can offer higher P efficiency for forage legume plants, and that struvite recovered from wastewater is particularly effective in the growth and P efficiency of alfalfa and red cover. Moreover, we've learned that in aquaculture, not all P-rich poop is equal! That excretion from African catfish has greater P mobilisation potential than from other aquaculture species.

New insights into physico-chemical processes of soil P binding and plant P availability: we have heard how computational chemistry is helping to improve understanding of the controlling the binding of P to soil, and how new insights into the relationships and conversions between routine operational P extraction methods is improving understanding of plant available soil phosphorus to maximise P availability to crops and minimise P losses to water bodies. We also learned that coating seeds with biofertilisers offers new opportunities to improve mineralisation and solubilisation of the existing more recalcitrant soil P pools, thus reducing the need for P fertilisers.

Environmental P challenges: Showcased in the poster sessions were projects covering P legacies in sediments and P cycling in soils and surface crusts, to the role of P in nuisance and harmful algal blooms in the Baltic Sea, and how hypoxia created by these P-fuelled algal blooms can impact invertebrates.

And alongside this soil, environmental and agricultural P science, we've heard about the cutting edge development and applications of P-based Organocatalysts and Biocatalysts; the synthesis of novel P compounds; and the role of phosphonium salts in medicinal chemistry and the production of pharmaceuticals.

And, from the molecular to the European scale, we've heard new assessment of policy instruments and the implications of the new phase of Common Agricultural Policy for ensuring public goods via new Eco-schemes and better P stewardship. We have also gained new insight into issues of Phosphorus Justice: balancing the many competing interests, demands and freedoms in the way that we manage land and vital P resources.

And next up, we'll be hearing the latest about the Molecular Biology of P research

Each and every one of these projects addresses the critical value and challenges of phosphorus to society.

And despite the world-wide challenges of the last two years of the pandemic, and the pressures this has imposed, it is wonderful to see the publication outputs continuing to

expand with an average of 50 peer-reviewed publications per year. It is also exciting to hear about the upcoming thematic workshops, including a Winter School on publishing in February, and a Summer School on Agriculture, Environment and Research in May.

And it is vital that this momentum in research and training created by the P Campus continues beyond 2024.

We are therefore delighted to hear about the proposed new initiatives that are being developed; a two pronged approach bringing together:

1. A DFG training group on P-metabolism and P-homeostasis, targeting that critical continuum between land and sea, including transitional ecotones such as dunes and wetlands, will train a new generation of molecular ecologists, biologists and environmental scientists and equip them with the skills needed to tackle the emerging environmental challenges arising from P, eutrophication along with and the converging climate-change pressures, in agriculture, and ecosystem management and protection; and

2. A Leibniz Research Alliance focusing on P in food, the environment, economy and ecology will expand the scope and cross-disciplinary co-operations between the wider range Leibniz institutes and their university partnerships, at supra-regional and international scales.

Critical to the success of the P campus has been the Coordination Office; and, on behalf on the Science Advisory Council, I'd like to thank Dana and Maxi for all their continued help and support. Maintaining this critical coordination office support will be vital for the continuing success of these new initiatives.

Over the last two years of the pandemic, we have all come to realise the fragility of our food systems and commodity chains within a globalised economy and, of course, our health systems. At the same time there has also been new recognition and understanding of the importance of the natural environment for our health and wellbeing.

The proposed new initiatives expand the research and training remit of P in agriculture, environment and governance, to include P in nutrition and medicine. This offers a unique opportunity to address aspects of the converging environmental and human health agenda and challenges, through the lens of phosphorus.

It is exciting to hear how that these proposed future directions and opportunities will build upon the tremendous achievements that the P Campus has made to date.

Congratulations, everyone – and thank you.

Members of the International Scientific Advisory Council of the P-Campus

Prof. Dr. Emmanuel Frossard, ETH Zurich, 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

Leibniz ScienceCampus Phosphorus Research Rostock

Tasks of the Coordination Office 2021

In the following, the activities and thematic foci of the Coordination Office of the Leibniz ScienceCampus Phosphorus Research Rostock in 2021 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 (PGS2) Leibniz Association (WGL). 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 2021, 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.

Due to the visibility of the P-Campus research, the Coordination Office was contacted in 2020 and 2021 by a scientist from **ZALF** (Leibniz Centre for Agricultural Landscape Research) and a scientist from the **Roman-Germanic Commission** of the German Archaeological Institute. It was possible in both cases to successfully establish contact with several scientists in the P-Campus.

In cooperation with ZALF, a concept for a third-party funded project was developed in 2020 and 2021, in which the mutual influence of the (bio) availability of Si and P from the soil via groundwater to surface waters (limnic and marine) will be investigated. In addition to ZALF, the University of Rostock and IOW, the IGB (Leibniz Institute of Freshwater Ecology and Inland Fisheries) is also involved in the intended cooperation. The project application has been largely prepared and is expected to be submitted to the BMBF in the next few months. The coordination office organized and documented the online meetings and coordinated the networking of the potential project partners.

A research collaboration is being sought with scientists from the Roman-Germanic Commission to evaluate soil phosphorus and vegetation in the context of archaeological research. For this purpose, two student research projects started in the winter

semester 2021/22, one with the WG Soil Science, the other with the WG Landscape Ecology at the Faculty of Agricultural and Environmental Sciences of the University of Rostock. If these projects are successful, they will serve as the basis for applications for third-party funding. Here, too, the coordination office not only initiated the contacts, but also organized and coordinated the meetings.

The **Leibniz Innovation Farm** for Sustainable Bioeconomy, initiated by the ATB (Leibniz Institute of Agricultural Engineering and Bioeconomy), started in 2021. Members of the P-Campus (from UR, IOW, FBN, and from the Sustainability and Climate Policy Research Unit) are involved in the workshops (animal husbandry, agronomy, systems analysis) that have been ongoing since 2021 for the development of project proposals. The P-Campus coordinator also attends the workshops and facilitates information and contacts between P-Campus members and the ATB.

Contacts with **external research institutes, ministries and authorities** were regularly maintained (e.g. 08.12.2021 presentation of recent research results of the P-Campus to ministry members).

Contacts to **other networks** were intensified, for example to the network Interdisciplinary Faculty (INF) and the DFG Graduate College Baltic Transcoast of the University of Rostock (e.g. stronger mutual exchange on events) and to the DPP (German Phosphorus Platform). There are also contacts with the Leibniz Science Campus ComBioCat, which are to be further expanded.

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 promised by the P-Campus with the official start of the second funding period in June 2019. The six projects have been successful, the last project (P-Cat) ended on Dec. 31, 2021, after a cost-neutral extension due to Corona restrictions. This successful seed project concept will continue for the second funding phase; the next call for proposals was originally planned for 2021. After coordination in the steering group, it was decided to tender the seed projects in 2022 and to use them to initiate the planned **Leibniz Research Network "Phosphorus in Agriculture, Environment and Food: Ecological Consequences and Societal Challenges"** or the **DFG Research Training Group "P-Metabolism in Land-Sea Gradients"**. 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 (online or presence) for both initiatives in 2021. At the **International P-Campus Symposium** (January 6-7, 2022), both research initiatives were presented to the Scientific Advisory Council and P-Campus members.

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). The **start-workshop 'P analytics'** was organized for November 2019 (CW 48) and the **P Breakfast** was organized and supervised by the Coordination Office on December 17, 2019. The P Breakfast and start-workshop 'P analytics' events planned for 2020 and 2021 for PhD students employed from 2020 onwards could not be realized due to Corona restrictions. A P-analytics workshop is now to be organized as part of a **Summer School in 2022**. The **Winter School "Publishing"** for the PhD students of the P-Campus and the University of Rostock, which was planned as a face-to-face event, had to be postponed to March 2022 due to coronary restrictions.

In 2021, the annual **Lecture Series of the P-Campus,** with a total of twelve lectures from May 2021 to January 2022, was organized by the P-Campus office as a webinar. Ten lectures were presented by the PhD students of the P-Campus. Since the lecture series are open to the public after registration, they were able to present their research topics and initial results to a broader audience. The **International P-Campus Symposium**, which was planned for November 2021, had to be postponed to January 2022. At this symposium, which was also attended by representatives of the International Scientific Advisory Council, eight P-Campus PhD students presented their research results as talks and five as posters.

Due to Corona restrictions, some PGS2 PhD projects were unable to conduct their 2020 and 2021 research as planned, resulting in time delays. The Coordination Office successfully took care of forwarding the application to WGL for corresponding Corona grants in the first quarter of 2021 for project II.3 P-Legumes. Over the course of 2021, application and approval of P-Campus internal funding for Projects IV.1 Soil Crusts and IV.3 Cyanoblooms (project extensions of four and six months, respectively) was also organized.

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 2021, this included, among other things, the organization of the P-Campus **Steering Group** meetings (including the presentation of current developments, taking minutes, etc.), the organization of online meetings for the initiation of a **Si-P project**, online meetings for an envisaged project with the **Roman-Germanic Commission**, the **International P-Campus Symposium** (online format) in January 2022 with the participation of the International Scientific Advisory Board, and the organization of the **annual year-end meeting** (online format) between representatives of the P-Campus and the Ministry of Education and Agriculture, respectively.

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).

Together with PhD students of the P-Campus, the P-Campus Coordination used to present different research topics of the P-Campus to a broad public at the "Long

Night of Sciences" at the University of Rostock every year. Due to the Corona restrictions, the event in 2021, as in 2020, could not take place in presence.

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 writing pads and flyers**. These measures were only possible to a very limited extent in 2021. The P-Campus Coordination also participated in the organization of the EWPC by the LIKAT, which was planned to take place in March 2021. However, due to the corona pandemic, it was decided in November 2020 to cancel the EWPC for 2021 and postpone it to March 2022. Since the EWPC is to be held as a face-to-face event, it has been postponed to September 2022 due to current developments. The P-Campus supports the EWPC with a financial contribution and the P-Campus Coordination will also actively support the EWPC on site and present the P-Campus.

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). The coordination office also compiles texts and information that allow the presentation of the P-Campus on other websites (for example, those of the DPP and the ESPP).

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