

# BLUE-GREEN BIODIVERSITY (BGB): OVERVIEW AND OUTLOOK<sup>1</sup>

## 1. Preamble

The Blue-Green Biodiversity (BGB) program was funded in two phases by the ETH Board in March 2020 on the basis of proposals submitted by WSL and Eawag (see Appendices 1 and 2). The first phase (BGB Initiation) was funded for 2020, and a 4-year continuation (BGB 2021-2024) was approved at the same time. The ETH Board stated its expectation that the BGB program would **promote cooperation** between Eawag and WSL and **increase the coherence, visibility, and impact of actionable** biodiversity research in the ETH Domain. (Actionable research is defined as research that informs decisions, improves policy design, or serves as the basis for implementation in practice.)

## 2. Rationale

Human well-being depends on ecosystem function and services. Despite this dependence, biodiversity, an essential attribute of ecosystems, has dramatically declined as a result of human activities. In Europe, hotspots of biodiversity can be found both in freshwater and terrestrial ecosystems and especially in their interface. Furthermore, mountain areas (such as widely found in Switzerland) are home to unique elements of biodiversity. Threats to biodiversity in Switzerland have been recognized nationally<sup>2</sup> and internationally.<sup>3</sup> Loss of biodiversity compromises Switzerland's progress toward achieving the Sustainable Development Goals (SDGs).<sup>4</sup> Redressing this loss is an explicit focus of the Swiss Strategy for Sustainable Development 2030<sup>5</sup> and is addressed by the Swiss Biodiversity Strategy and Action Plan.<sup>6</sup>

An important deficit in biodiversity research is that freshwater and terrestrial ecosystems are commonly studied in isolation from each other. This belies the reality that resources and chemical substances flow across land-water boundaries and many organisms cross these boundaries, often spending different life stages in different habitats. Many ecological and evolutionary processes are common to both terrestrial and aquatic ecosystems and underlie their interdependency. The integrated BGB initiative will fill knowledge gaps relating, for example, to the importance of connectivity for the generation and maintenance of biodiversity and to the influence of biodiversity on ecosystem functioning. The BGB initiative will also build capacities to design, implement, and manage measures to conserve and restore biodiversity, thus contributing to the mitigation of biodiversity loss (covering species, genetic, phenotypic, and functional diversity) and fulfilling the commitments to restore biodiversity under Agenda 2030.

<sup>1</sup> This document was drafted by J. Hering (Eawag) in collaboration with C. Hegg (WSL), F. Altermatt (Uni Zurich / Eawag) and C. Graham (WSL). Input from other members of the BGB core team is gratefully acknowledged.

<sup>2</sup> FOEN (2017) Biodiversity in Switzerland: Status and Trends, <https://www.bafu.admin.ch/bafu/en/home/topics/biodiversity/publications-studies/publications/biodiversity-in-Switzerland-status-and-trends.html>

<sup>3</sup> OECD (2017) Environmental Performance Reviews SWITZERLAND 2017, <https://www.oecd.org/publications/oecd-environmental-performance-reviews-switzerland-2017-9789264279674-en.htm>

<sup>4</sup> Dao et al. (2018) National environmental limits and footprints based on the Planetary Boundaries framework: The case of Switzerland. *Global Environ. Change* **52**, 49-57

<sup>5</sup> <https://www.news.admin.ch/news/message/attachments/63586.pdf>

<sup>6</sup> FOEN (n.d.) Swiss Biodiversity Strategy and Action Plan, <https://www.bafu.admin.ch/bafu/en/home/topics/biodiversity/info-specialists/massnahmen-zur-erhaltung-und-foerderung-der-biodiversitaet/strategie-biodiversitaet-schweiz-und-aktionsplan.html>.

### 3. The BGB Initiative

The motivating concept behind the BGB Initiative is that an integrated consideration of aquatic and terrestrial ecosystems would ultimately benefit the conservation, maintenance and restoration of biodiversity. Thus, projects in the BGB Initiative explicitly include linkages between aquatic and terrestrial ecosystems, processes occurring at the interfaces of these systems, and their relative sensitivity to drivers of biodiversity change. Two initial questions that are central to the BGB Initiative are already being addressed in the context of the BGB Initiation (2020) projects:

- *How should different facets of biodiversity in aquatic and terrestrial ecosystems be characterized and compared to understand their responses to anthropogenic change and other drivers?*
- *How can an evidence-based understanding of biodiversity be used to improve policy and decision making?*

These questions, particularly the second one, will continue to be studied in BGB 2021-2024. Additional questions, building on this foundation, will include:

- *How will blue-green ecosystems and their biodiversity respond to climate (and other environmental) change?*
- *How should conservation strategies and urban development be aligned to best preserve both aquatic and terrestrial biodiversity in Switzerland?*
- *What are the characteristics of species interactions and ecosystem processes, such as carbon recycling or toxin production, across aquatic and terrestrial ecosystems?*
- *How must socio-ecological interdependencies and existing knowledge and attitudes of stakeholders and the public be considered to optimize the outcome of ecological restorations?*
- *How should we design training and teaching materials to propagate the concept of blue-green biodiversity to stakeholders and decision makers?*

**3.1. BGB Governance.** The Directors of Eawag and WSL, who submitted the proposal to the ETH Board, also bear overall responsibility for the BGB program and serve as contacts for the ETH Board. Financial management and reporting are the responsibility of the leading house (i.e., WSL for BGB Initiation (2020) and Eawag for BGB 2021-2024). The Eawag and WSL Directors recruited a BGB core team with members and co-leaders from both institutions.<sup>7</sup> The core team functions as an advisory body for the Directors, as an interface with the larger biodiversity community at Eawag and WSL, and takes a leading role in promoting synthesis and outreach activities.

**3.2 BGB Projects.** The principal activities within the BGB Initiative are the funded projects.<sup>8</sup> For BGB Initiation, these 1-year projects focus on the analysis and/or modelling of *existing* data, using datasets developed by Eawag and WSL as well as other organizations and consortia. For BGB 2021-2024, multiyear funding allows for recruitment of doctoral students who will collaborate with postdoctoral researchers working on research/education (RE)

<sup>7</sup> Co-lead: F. Altermatt (UZH/Eawag), C. Graham (WSL); Eawag members: I. Logar (from September), B. Matthews, A. Narwani (through August 2020 and from March 2021), Ole Seehausen (UBE/Eawag, through February 2021); WSL members: M. Gossner, R. Holderegger, M. Hobi

<sup>8</sup> <https://www.eawag.ch/en/research/water-for-ecosystem/biodiversity/blue-green-biodiversity-research-initiative/>, <https://www.wsl.ch/en/about-wsl/programmes-and-initiatives/blue-green-biodiversity-research-initiative.html>

projects funded through the BGB 2021-2024 call.<sup>9</sup> BGB implementation (IM) projects include an explicit theory of change and will serve as a bridge between research, policy, and practice.

3.3. BGB Early Career Researcher (ESR) Community. The training of doctoral students and postdoctoral researchers will be a major contribution of the BGB project to the biodiversity community and its stakeholders. Through their involvement in data integration, modeling and synthesis, these early career scientists will be well prepared to engage in the conservation and restoration of biodiversity. Although doctoral students and postdoctoral researchers will be affiliated with specific projects, some coordinated recruiting efforts will be encouraged. This approach was very successful in recruiting an excellent cohort of postdoctoral researchers for the BGB Initiation projects in 2020. Gender and other diversity aspects are explicitly considered in the recruiting process. Some BGB funds are reserved to provide professional support for the ESR cohort of doctoral students and postdoctoral researchers.

3.4. BGB Open Data. It is expected that many BGB projects will include the compilation of data and their structuring for interoperability. Compliance with the Open Research Policy of the ETH Domain<sup>10</sup> will ensure that these efforts will benefit not only the BGB community but also the wider scientific community. Data and metadata will be hosted at WSL (EnviDat<sup>11</sup>) and/or Eawag (ERIC<sup>12</sup>).

3.5. BGB synthesis. Synthesis will be a core element of the BGB initiative, providing cohesion for the BGB projects and increasing their visibility and impact. All BGB project leaders will contribute to an overall synthesis during and at the end of their projects under the leadership of the BGB core team. A key objective will be to make the results of BGB projects accessible to a broad Swiss stakeholder community. BGB funding will also be used to support synthesis activities.

3.6. BGB Communication and Outreach to Stakeholders. The Eawag and WSL websites host (mirror) BGB webpages,<sup>7</sup> which serve as a primary communication channel. News stories from both institutions<sup>13</sup> also highlight BGB activities. Future outreach and communication will be tailored to BGB project outputs and the synthesis. Targeted outreach activities will be carried out either by dedicated BGB staff or external providers. Such outreach will be integrated with direct contact with stakeholders to foster uptake and implementation of knowledge. The IM projects funded through BGB 2021-2024 will be a key element of the overall outreach strategy for the BGB Initiative.

3.7. Additional BGB activities in 2023-2024. The allocation of funding for the BGB 2021-2024 projects and ancillary support still leaves some funds in reserve for project and other activities in 2023-2024 (with the proviso that doctoral research projects will likely extend into the first half of 2025). Possible uses for reserve funding are under consideration, which would include conducting targeted synthesis and outreach activities and/or recruiting a small cohort of BGB postdoctoral fellows (i.e., independent early career researchers who would

<sup>9</sup> <https://www.internal.eawag.ch/en/legal-basis/directives-internal-regulations/directives/2020/20-13/>, <https://intra.wsl.ch/de/direktion/calls-der-direktion/call-bgb2021-2024> (both links for INTRANET ONLY)

<sup>10</sup> [https://www.ethrat.ch/sites/default/files/ORD\\_Position\\_ETH\\_Domain.pdf](https://www.ethrat.ch/sites/default/files/ORD_Position_ETH_Domain.pdf)

<sup>11</sup> <https://www.envidat.ch/#/>

<sup>12</sup> <https://opendata.eawag.ch/>

<sup>13</sup> <https://www.eawag.ch/en/news-agenda/news-portal/news-archive/archive-detail/we-need-to-study-biodiversity-in-a-more-holistic-way/>; <https://www.wsl.ch/en/2020/05/we-need-to-study-biodiversity-in-a-more-holistic-way.html>

bring in new ideas and perspectives). It is also expected that projects associated with the BGB initiative would be initiated with *external funding* acquired by BGB researchers.

#### **4. Outlook**

The BGB Initiative builds on the strength of biodiversity research at WSL and Eawag. By integrating across terrestrial and aquatic ecosystems, BGB research will identify insights into overlooked processes that maintain biodiversity or, conversely, that result in the reduction of biodiversity in response to anthropogenic drivers. The integration of blue and green ecosystems would provide a basis to reduce, or even reverse, biodiversity loss associated with habitat fragmentation, invasive species, climate change and other drivers.

There are a number of key elements that will contribute to the success of the BGB initiative:

- Strong biodiversity research communities at WSL and Eawag
- Good experience with stakeholder engagement at WSL and Eawag
- Establishment of an early career researcher community in BGB
- Parallel funding of research/education (RE) and implementation (IM) track proposals
- Commitment to synthesis and outreach

With the current rate of biodiversity loss, rapid uptake of effective conservation and restoration measures becomes ever more necessary. Such rapid uptake requires meaningful knowledge exchange between science, practice and policy. The synthesis of results from the BGB projects and coordinated outreach activities will serve to accelerate the implementation of evidence-based measures for biodiversity conservation and restoration.

#### **Appendices**

Appendix 1. Eawag-WSL Collaborative Proposal (2020) – Blue-Green Biodiversity (BGB) Initiation

Appendix 2. Eawag-WSL Collaborative Proposal (2021-2024) – Blue-Green Biodiversity (BGB)

## Eawag-WSL Collaborative Proposal (2020) – Blue-Green Biodiversity (BGB) Initiation

### Community building, horizon scanning, adding value to data, and generating visibility for biodiversity at the interface of aquatic and terrestrial ecosystems

**Why biodiversity.** Biodiversity is essential to human life and welfare. Understanding, managing, and protecting biodiversity is critical to achieving the Sustainable Development Goals (SDGs). Due to human activities, biodiversity is decreasing at unprecedented rates, worldwide, in Europe, and in Switzerland. For Switzerland, the loss of biodiversity is one of the leading impediments to achieving the SDGs<sup>1</sup> and a national Biodiversity Action Plan was adopted in 2017.<sup>2</sup> At a political level, biodiversity loss has been put on the agenda of the 2020 World Economic Forum.<sup>3</sup> At the same time, reaching the SDGs can involve trade-offs. Biodiversity, as captured in SDGs 14 (*Conserve and sustainably use the oceans, seas and marine resources...*) and 15 (*Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests... and halt biodiversity loss*), can, in particular, be compromised by progress toward other SDGs<sup>4</sup> or, in industrialized countries like Switzerland, by past and present alterations to the landscape (such as diversions of waterways), changes in land-use, and other human activities intended to benefit society.

**Vital interdependencies between freshwater and terrestrial ecosystems.** Freshwater and terrestrial ecosystems and their interfaces are hotspots for biodiversity and its underlying evolutionary processes. The severe threats to biodiversity in many of these systems, including in Switzerland, rarely receives sufficient attention. A focus on the interdependencies of aquatic and terrestrial systems is needed to strengthen the understanding of their interactions, commonalities and differences.

**An Eawag-WSL collaboration focusing on Blue-Green Biodiversity (BGB).** Integrated BGB research incorporates the ecological and evolutionary processes that are common to both terrestrial and aquatic ecosystems and that underlie their interdependency. Resources and chemical substances flow across land-water boundaries and many organisms cross these boundaries, often spending different life stages in different habitats. Eawag and WSL have a successful history of collaboration on this topic, especially as applied to river restoration.<sup>5</sup> However, the interdependencies between aquatic and terrestrial ecosystems should be examined in a much broader way, addressing many pressing research questions relevant for application and outreach. A new BGB initiative is called for to address the increasing concerns about biodiversity loss (covering species, genetic, phenotypic, and functional diversity) and the commitments to restore biodiversity under Agenda 2030. The initiative comes at exactly the right time to integrate the expertise at WSL and Eawag and to capitalize on new technological opportunities (e.g., remote sensing,<sup>6</sup> ancient and environmental DNA<sup>7</sup> analysis) and the availability of large biodiversity data sets. Eawag and WSL have created and host many of these data sets<sup>8</sup> and have substantial experience in developing methods for improved data acquisition,<sup>9</sup> modeling, analysis, and interpretation of biodiversity data.

**BGB Initiation in 2020.** Activities in 2020 will focus on: (1) community building, horizon scanning and priority setting, (2) adding value to existing data through modelling, (3) developing and initiating the implementation of outreach and translation, and (4) establishing research directions for Eawag and WSL collaboration in the 2021-2024 BGB project.

These efforts will take advantage of the well-established biodiversity research in Switzerland, not only at Eawag and WSL, but also at ETHZ and EPFL as well as at the Cantonal Universities. Prominent Eawag and WSL biodiversity researchers are already well embedded in the national context including, but not limited to, adjunct appointments at ETHZ (Gessler,<sup>WSL</sup> Holderegger,<sup>WSL</sup> Kienast,<sup>WSL</sup> Rigling,<sup>WSL</sup> Vorburger,<sup>Eawag</sup> Zimmerman<sup>WSL</sup>) and joint appointments at EPFL (Grossiord<sup>WSL</sup>), ETHZ (Jokela<sup>Eawag</sup>, Pellisier<sup>WSL</sup>), Uni Bern

<sup>1</sup> Dao et al. (2018) National environmental limits and footprints based on the Planetary Boundaries framework: The case of Switzerland. *Global Environ. Change* **52**, 49-57; FDFA (2018) Switzerland implements the 2030 Agenda for Sustainable Development. Federal Department of Foreign Affairs, 26 pp. [https://www.eda.admin.ch/dam/agenda2030/en/documents/laenderbericht-der-schweiz-2018\\_EN.pdf](https://www.eda.admin.ch/dam/agenda2030/en/documents/laenderbericht-der-schweiz-2018_EN.pdf)

<sup>2</sup> FOEN (n.d.) Swiss Biodiversity Strategy and Action Plan, <https://www.bafu.admin.ch/bafu/en/home/topics/biodiversity/info-specialists/massnahmen-zur-erhaltung-und-foerderung-der-biodiversitaet/strategie-biodiversitaet-schweiz-und-aktionsplan.html>.

<sup>3</sup> <https://www.weforum.org/agenda/2020/01/nature-risk-biodiversity-climate-ocean-extinction-new-deal/>

<sup>4</sup> Independent Group of Scientists (2019) Global Sustainable Development Report 2019: The Future is Now – Science for Achieving Sustainable Development. United Nations, 216 pp. <https://sustainabledevelopment.un.org/gsd2019>.

<sup>5</sup> (current) Hydraulic Engineering and Ecology (<https://www.rivermanagement.ch/en/>), (2007-2010) Integrated River Management, (2002-2006) Rhone-Thur. (EPFL (LCH) and ETH Zurich (VAW) were and continue to be strongly engaged in these projects.)

<sup>6</sup> (E.g., from Eawag) Nouchi, V., et al. (2019). "Resolving biogeochemical processes in lakes using remote sensing." *Aquat. Sci.* **81**(2). (E.g., from WSL) Hobi M and Ginzler C (2012) Accuracy assessment of digital surface models based on WorldView-2 and ADS 80 stereo remote sensing data. *Sensors*, **12**: 6347-6368.

<sup>7</sup> Deiner, K., et al. 2016. Environmental DNA reveals that rivers are conveyor belts of biodiversity information. *Nat. Com.* **7**:12544.

<sup>8</sup> (Eawag) Progetto Lac, Progetto Fiumi, Amphipod.CH; (WSL) Hartmann M. et al. (2017) A decade of irrigation transforms the soil microbiome of a semi-arid pine forest. *Mol. Ecol.*, doi: 10.1111/mec.13995.

<sup>9</sup> (E.g., from Eawag) Pomati, F., et al. (2011). "An Automated Platform for Phytoplankton Ecology and Aquatic Ecosystem Monitoring. *Environ. Sci. Technol.* **45**: 9658-9665.

(Seehausen<sup>Eawag</sup>), and Uni Zurich (Altermatt<sup>Eawag</sup>). The links to the Cantonal Universities are particularly important since they provide connections to the Wyss Academy for Nature (Uni Bern) and the University Research Priority Program (URPP) on Global Change and Biodiversity (Uni Zurich). With this level of activity, it is important that the BGB Initiation project leverages synergies with partner institutions and establishes visibility for the Eawag-WSL focus on the interdependencies of terrestrial and aquatic systems.

- **Community building, horizon scanning and priority setting.** Biodiversity researchers at Eawag and WSL will conduct a series of workshops, informal discussions, and exchanges of seminar speakers to identify questions of scientific importance and/or high societal or policy-relevance for biodiversity conservation with a particular emphasis on the interdependency of aquatic and terrestrial ecosystems and their interfaces. This will extend the analysis co-led by researchers from WSL and ETH Zurich,<sup>10</sup> which identify questions including: *How can ecological connectivity maintain the adaptive capacity of ecosystems in the face of environmental change? What is the impact of gene flow through an ecological continuum on genetic adaptation to climate change? and How can the spread of invasive species and diseases be minimized, while ensuring connectivity for native species?* The implications of questions such as these for biodiversity will be discussed at a group-seminar on April 24. Further, emerging topics and trends in biodiversity research will be discussed (e.g. effects of micro- or nanoplastics and other pollutants, adaptation to climate change, genetic erosion of species differences, novel species interactions). Trained facilitators will lead discussions and follow up with interviews and surveys. These activities will provide a basis for concept papers on the importance of the aquatic-terrestrial interface and interdependencies for biodiversity and ecosystem function and for the detailed refinement of topics for the subsequent BGB project in 2021-2024 (see separate proposal).
- **Analysis and modelling of existing data.** Eawag and WSL host large data sets on aquatic and terrestrial biodiversity as well as environmental data. Data for terrestrial and aquatic indicator groups are available through the Swiss Biodiversity Monitoring (BDM) program<sup>11</sup> and remote sensing data is available through the ARES consortium (<https://ares-observatory.ch/>), led by Uni Zurich with participation by Eawag and WSL as well as other ETH Domain institutions. We propose to initiate joint Eawag-WSL projects by adding value to these data through collaborative analysis and modelling. Postdoctoral researchers, supported by data specialists, will carry out coherent and integrated data analyses to identify trends and drivers of biodiversity change in aquatic and terrestrial ecosystems in Switzerland. This will provide rapid output, visibility and a basis for identifying study systems, field sites and experiments for 2021-2024.
- **Outreach and translation.** Outreach and translation efforts are critical for the effective implementation of conservation measures.<sup>12</sup> Web-based platforms, such as the award-winning [waldwissen.net](http://waldwissen.net), can be valuable channels to provide relevant information to stakeholders. Eawag and WSL will evaluate outreach options including a partnership with the existing platform Informationsdienst Biodiversität Schweiz IBS. Close cooperation with the Biodiversity Forum will be facilitated by the engagement of Eawag and WSL-affiliated researchers in the Forum, including the current President, Prof. Altermatt.

**Project budget and governance.** For formal reasons, this proposal is being submitted by the Directors of Eawag and WSL; they will continue to bear overall responsibility for the project and to serve as contacts for the ETH Board. The Eawag and WSL Directors will each nominate a co-leader for the project, who will form a core team with three additional senior researchers from each institute. The core team will be responsible for engaging the broader biodiversity community, particularly at Eawag and WSL, but also at other institutions within and beyond the ETH Domain. The co-leaders, with input from other core team members, will be responsible for delivering detailed plans for specific sub-projects to the Eawag and WSL Directorates for approval. The core team will also further develop the science plan for the 2021-2024 BGB project (see separate proposal). Reporting to the ETH-Board will go through WSL as the leading house, which will be responsible for financial management.

The total budget of CHF 1.5 Mio (for 2020) corresponds to the funding reserved for the 4RI<sup>3</sup> initiative.<sup>13</sup> Of this, 1.1 Mio will be for personnel, including post-doctoral researchers working on data integration and analysis, non-tenure track scientists to assist with coordination of horizon-scanning activities, a part-time administrative assistant for the core team, and to offset time commitments of some permanent staff. Further expenditures (0.4 Mio) will be used for professional facilitation, data storage, workshop expenses, and outreach activities.

<sup>10</sup> Walzer, C., et al. (2013). "The 50 most important questions relating to the maintenance and restoration of an ecological continuum in the European Alps. *PLOS One* 8(1).

<sup>11</sup> <http://www.biodiversitymonitoring.ch/en/home.html>

<sup>12</sup> Fabian Y., et al. (2019). "How to close the science-practice gap in nature conservation? Information sources used by practitioners." *Biol. Conserv.* 235: 93-101.

<sup>13</sup> In its March meeting in 2019, the ETH Board reserved CHF 1.50 Mio for a proposed project called the 4 Research Institute Interface Initiative (4RI<sup>3</sup>). In the context of later discussions of structure and governance in the ETH Domain, the 4RI<sup>3</sup> concept is not viable.

## Eawag-WSL Collaborative Proposal (2021-2024) – Blue-Green Biodiversity (BGB)

**Preamble.** The BGB project (2021-2024) will expand and continue the 2020 BGB Initiation project,<sup>1</sup> which has been submitted to the ETH Board for separate funding in 2020. For brevity, only key points regarding the motivation for this project and the relevant competences of Eawag and WSL are repeated here.<sup>2</sup>

**Blue-green biodiversity (BGB).** Biodiversity is essential to human life and welfare. Freshwater and terrestrial ecosystems and their interfaces in mountain areas are hotspots of biodiversity in Europe. Biodiversity in these aquatic and terrestrial ecosystems is severely threatened worldwide, including in Switzerland, but is seldom a focus of consolidated research. Perhaps the most significant deficit is that freshwater and terrestrial ecosystems are often studied in isolation from each other. A consolidated focus on biodiversity dynamics at the catchment scale including the explicit interfaces between aquatic and terrestrial ecosystems is needed to highlight the interactions between these ecosystems and their interdependencies. Integrated BGB research considers landscapes with intimately interdependent terrestrial and aquatic biomes, reflecting the fact that resources, chemicals and particles flow across land-water boundaries<sup>3,4</sup>, and that many organisms cross these boundaries and may spend some of their life stages in different habitats.<sup>5</sup> Loss of biodiversity compromises Switzerland's progress toward achieving the Sustainable Development Goals (SDGs).<sup>6</sup> The 2017 Swiss Biodiversity Action Plan<sup>7</sup> is intended to redress this problem but the scientific understanding and evidence bases for the selection, implementation, and management of ecosystem conservation and restoration measures are insufficient. BGB questions are also central to the 2019 IPBES recommendations to practice integrated water resource management and landscape planning across scales, slow and reverse revegetation of catchments and mainstream practices that reduce erosion, sedimentation and pollution run-off as "pathways to a sustainable future".<sup>8</sup>

**History of Eawag-WSL collaboration.** WSL and Eawag have a strong history of collaboration across a broad range of topics, including biodiversity and river restoration, which also involves EPFL/LCH and ETH Zurich/VAW).<sup>9</sup> In 2019, Eawag and WSL made their first joint appointment of a scientific collaborator, Dr. Holzner. Furthermore, both Eawag and WSL have extensive expertise in collecting and analyzing biodiversity data, having pioneered the development of many methods in this field and their applications, such as Eawag's work on environmental DNA (e-DNA)<sup>10</sup> and WSL's work on biodiversity modelling.<sup>11</sup> Eawag and WSL are also strongly embedded in the national biodiversity community, in part through appointments of their senior researchers as adjunct professors as well as joint professorial appointments with EPFL, ETH Zurich and the Cantonal Universities in Bern and Zurich.<sup>2</sup> The links to the Cantonal Universities are particularly important since they provide connections to the Wyss Academy for Nature (Uni Bern) and the University Research Priority Program (URPP) on Global Change and Biodiversity (Uni Zurich). Furthermore, Prof. Altermatt (jointly appointed by Uni Zurich and Eawag) is President of the SCNAT Biodiversity Forum, which provides important links to national stakeholders.

**Focus areas and priority questions for the BGB project.** In 2020, we will identify the core set of questions and projects which will be studied in depth in the 2021–2024 period. We note that an insufficient understanding of the links between biodiversity and ecosystem functioning may limit the motivation to conserve biodiversity. We will fill these knowledge gaps and build capacities to design, implement, and manage measures to conserve and restore biodiversity. One fundamental goal is to work towards a dynamic biodiversity model for Swiss landscapes that builds on the rich datasets that WSL and Eawag have been working on over the last decades. Target research questions will be scientifically challenging and directly relevant for application and/or outreach. Examples could include: *Are aquatic and terrestrial biodiversity*

<sup>1</sup> Note that the BGB project description (and budget) is predicated on full funding of the BGB Initiation project in 2020.

<sup>2</sup> For further details, see the BGB Initiation proposal.

<sup>3</sup> Gounand, I., et al. (2018). "Cross-ecosystem carbon flows connecting ecosystems worldwide." *Nat. Comm.* **9**.

<sup>4</sup> Kayler, Z.E. et al (2018) Integrating aquatic and terrestrial perspectives to improve insights into organic matter cycling at the landscape scale. *Front. Earth Sci.* **7**.

<sup>5</sup> Muehlbauer, J.D., et al. How wide is a stream? Spatial extent of the potential "stream signature" in terrestrial food webs using meta-analysis. *Ecology* **95**

<sup>6</sup> Dao et al. (2018). National environmental limits and footprints based on the Planetary Boundaries framework: The case of Switzerland. *Global Environ. Change* **52**, 49-57; FDFA (2018) Switzerland implements the 2030 Agenda for Sustainable Development. Federal Department of Foreign Affairs, 26 pp. [https://www.eda.admin.ch/dam/agenda2030/en/documents/laenderbericht-der-schweiz-2018\\_EN.pdf](https://www.eda.admin.ch/dam/agenda2030/en/documents/laenderbericht-der-schweiz-2018_EN.pdf)

<sup>7</sup> FOEN (n.d.) Swiss Biodiversity Strategy and Action Plan, <https://www.bafu.admin.ch/bafu/en/home/topics/biodiversity/info-specialists/massnahmen-zur-erhaltung-und-foerderung-der-biodiversitaet/strategie-biodiversitaet-schweiz-und-aktionsplan.html>.

<sup>8</sup> [https://ipbes.net/sites/default/files/ipbes\\_global\\_assessment\\_chapter\\_5\\_unedited\\_31may.pdf](https://ipbes.net/sites/default/files/ipbes_global_assessment_chapter_5_unedited_31may.pdf)

<sup>9</sup> (current) Hydraulic Engineering and Ecology (<https://www.rivermanagement.ch/en/>), (2007-2010) Integrated River Management, (2002-2006) Rhone-Thur

<sup>10</sup> Deiner, et al. (2016). Environmental DNA reveals that rivers are conveyor belts of biodiversity information. *Nat. Com.* **7**:12544.

<sup>11</sup> Wisz et al. (2013). [The role of biotic interactions in shaping distributions and realised assemblages of species: implications for species distribution modelling.](#) *Biol. Rev.* **8**: 15–30.

*correlated and, if so, at what scale? To what extent do similar or different processes dominate dynamics in aquatic and terrestrial ecosystems and why? Does biodiversity in one of these ecosystems affect ecosystem dynamics in the other ecosystem and, if so, how? Does the role of river systems in the longitudinal conveyance of biodiversity also hold for lateral connectivity in terrestrial ecosystems? and How are biodiversity and ecosystem function related?* The BGB priority questions will be addressed by a broad array of methods including field surveys and controlled experiments, remotely sensed data (e.g. from drones), mechanistic modelling of available data from large-scale surveys and prior field studies.<sup>2</sup> Novel approaches such as e-DNA<sup>9</sup> and a-DNA,<sup>12</sup> next generation sequencing and metabarcoding of water, soils and sediments will be applied to study and understand the processes that create and maintain species, genetic and functional diversity.

**Capitalizing on existing field infrastructure.** Switzerland hosts extraordinary diversity which is subject to strong anthropogenic pressures.<sup>13</sup> The Alps, for example, offer aquatic and terrestrial ecosystem gradients that could support the questions of a broad community of biodiversity researchers. The current infrastructure and field sites that Eawag and WSL manage is world-class and the foundation for such gradient analysis. This will allow an accelerated start of the field studies and experiments during the 2021-2024 project period.

**BGB data integration, modeling and synthesis.** A core goal, already envisioned in 2020, is to develop and test models of biodiversity change that explicitly incorporate key ecological, evolutionary and societal processes. BGB data analysis will begin by mining and analyzing existing data that were prepared and compiled as part of the BGB Initiation project. These results will serve as a basis for designing the experiments and field studies, particularly with regard to data collection and modelling.

**The BGB research cohort.** Building on the community established in 2020 (group leaders and recruited postdocs), we plan to recruit a cohort of additional postdocs and doctoral students, who would conduct their dissertation doctoral research over the 2021-2024 BGB project period. Having such a doctoral cohort will create a community of graduate students, who will additionally benefit from opportunities provided by the Life Science Zurich Graduate School and the Uni Bern/CUSO graduate school in Ecology & Evolution<sup>14</sup>. Dedicated BGB doctoral retreats may be organized for intensive data analysis and/or writing activities.

**Additional BGB-related projects.** It is anticipated that the vibrant BGB community will naturally generate a variety of project ideas, many of which will be able to attract external funding. Internal funding (e.g., for seed projects) will also be accommodated based on proposals reviewed by an external scientific advisory board.

**Anticipated BGB outputs: training, synthesis, and outreach.** The training of doctoral students and postdoctoral researchers will be a major contribution of the BGB project to the biodiversity community and its stakeholders. Through their involvement in data integration, modeling and synthesis, these early career scientists will be well prepared to engage in the conservation and restoration of biodiversity. BGB data will be deposited in open access repositories.<sup>15</sup> The BGB project team will develop a clear strategy for synthesis and outreach, with products such as fact sheets, policy briefs, or open information platforms on the web. Target venues for the scientific community include highly visible outlets (e.g., the *Annual Reviews* series).

**Project budget and management.** For formal reasons, this proposal is being submitted by the Directors of Eawag and WSL, who will continue to bear overall responsibility for the project and to serve as contacts for the ETH Board. The project will be managed by the BGB core team, which will be adapted from the BGB Initiation core team.<sup>2</sup> This development of the BGB management will be transparent and inclusive. The two co-leaders of the core team (one from Eawag and one from WSL) will be responsible for coordinating the elements described above. They are also expected to exchange with and report to the WSL and Eawag Directorates. Eawag will serve as leading house for financial management and reporting to the ETH-Board.

The budget request for the BGB 2021-24 initiative is CHF 5 Mio to be distributed across the project period with 1.6 Mio in years 1 and 2, 1.0 Mio in years 3, and 0.8 Mio in year 4, reflecting the replacement of project funding with alternative funding sources as the project ends. Some investment in infrastructure (not to exceed 0.4 Mio) will be made based on planning in 2020. Funding of 0.5 Mio is requested for consumables and other research-related expenses and of 0.3 Mio for synthesis and outreach activities. The major part of the funding (3.8 Mio) will be used for personnel (including administrative support not to exceed 5% of personnel support and limited offsetting of time commitments by some permanent staff). Note: the salary costs of the BGB doctoral cohort will be approximately 1.57 Mio (including social costs) for 4 years, allowing room in the budget for postdoctoral researchers and technical staff (e.g., data specialists).

<sup>12</sup> Monchamp, M.E. et al. (2018) Homogenization of lake cyanobacterial communities over a century of climate change and eutrophication. *Nature Ecol. Evol.* **2**, 317-+.

<sup>13</sup> Walzer, C. et al. (2013). The 50 Most important questions relating to the maintenance and restoration of an ecological continuum in the European Alps. *Plos One* **8**(1).

<sup>14</sup> Enrollment in a graduate school will be required. E.g., <https://www.lifescience-graduateschool.uzh.ch/en.html> or [https://www.unibe.ch/studies/programs/doctorate/doctoral\\_degree\\_programs/cuso\\_doctoral\\_degree\\_programs/index\\_eng.html](https://www.unibe.ch/studies/programs/doctorate/doctoral_degree_programs/cuso_doctoral_degree_programs/index_eng.html)

<sup>15</sup> E.g., <https://opendata.eawag.ch/>