

WSL MAGAZINE

# DIAGONAL

FOCUS

## Biodiversity: Living varieties under pressure

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## EDITORIAL

Dear reader

As a climatologist, I am studying the evolution of the Greenland ice sheet. Anyone who has ever met me will know that I am very concerned about the effects of climate change: the rising levels of the world's oceans, extreme weather events and the expansion of deserts. These threaten the existence of millions of people. But climate change is also leading to changes in biodiversity. This issue of Diagonal focuses on how we research and document biodiversity, as well as on how it is changing – whether due to climate change or human activities. The wider society can – indeed should – use these findings to counteract loss. At the international level, researchers from all over the world play a part in the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES). They assemble information published in peer-reviewed journals on biodiversity following the example of the IPCC on climate change, where I have been active for many years. I am delighted that WSL experts are also involved in IPBES.



Prof. Dr. Konrad Steffen  
Director of WSL



# Biodiversity



## BASIS OF LIFE

Biodiversity is not only useful, but also has idealistic value. Researchers at WSL are investigating what it takes to protect natural diversity.

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## LICHENS UNDER THE MAGNIFYING GLASS

Twenty years ago, more than a third of the lichen species in Switzerland were on the Red List as 'endangered'. The state of these organisms today is the subject of a new survey.

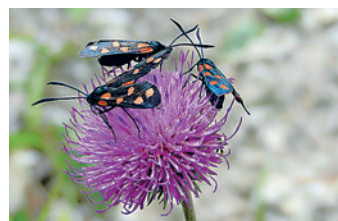
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## HABITATS IN THE LAB

How diverse must an ecosystem be for it to function? WSL researchers are addressing this question by experimenting with woodlice, snails and earthworms.

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BIODIVERSITY Humans depend on natural diversity. WSL researchers are investigating how it can be protected.

# Why biodiversity concerns us all

Clearing stands affected by storms less thoroughly and leaving more bark beetle trees can compensate to a considerable extent for the potential future loss of the Three-toed woodpecker's habitat.

A WSL research programme used model calculations to show that spruce forests in the mountains are declining under climate change. As a result, the habitat of the Three-toed woodpecker in Switzerland will probably shrink by about one fifth by 2050.





As a lover of bark beetles, the Three-toed woodpecker benefits from the today's forest management in which beetle-infested trees are no longer consistently removed from forests and deadwood is actively promoted.

Three-toed woodpecker (*Picoides tridactylus*) beside the opening to its nesting cavity.

Photo: Markus Varesvuo

Diversity is beautiful. Most people find a meadow covered with red, blue, yellow and white flowers more attractive than an endless field of corn, and a species-rich, well-structured forest preferable to a uniform spruce plantation. Many are delighted when they spot a rare bird. Millions and millions of organisms of all shapes, colours and sizes populate the earth and enrich our world of experience. But many of these creatures are now endangered or disappear at a rate our planet has never seen before. That is why researchers are already talking about the sixth mass extinction in Earth's history.

Biological diversity is in bad shape in Switzerland as well. According to the Federal Office for the Environment's (FOEN) 2017 report 'Biodiversity in Switzerland: State and Development', half of Switzerland's habitats and one third of its species are endangered, which is significantly more than in most EU countries. "In particular, species that are ecologically specialised and rare are not doing well," says Rolf Holderegger, Head of WSL's Biodiversity and Conservation Biology Research Unit. They often depend on special habitats such as dry grasslands, fens or raised bogs, which are continuing to lose quality and are often shrinking in area as well.

All three levels of biodiversity are affected: species, habitats and genetic diversity, which is central to the adaptability and long-term survival of species. For agricultural land, the picture is particularly grim as valuable habitats have been impaired through intensive use and nutrient input. In forests, the situation is better because they are mostly managed in a 'close-to-nature' way with an increasing amount of deadwood left standing or lying.

## More than honey

Diverse ecosystems provide important services – so-called ecosystem services – better than uniform ones: wild bees pollinate crops, soil organisms provide healthy soils, and forests clean air and water. Forests also positively influence the climate and provide protection against floods and avalanches. The loss of biodiversity gives rise to economic costs – estimated to reach around four percent of the EU's gross domestic product by 2050.

Both the Swiss Federal Constitution (Art. 78) and international treaties such as the Convention on Biological Diversity (CBD) stipulate that biological diversity should be protected – not just for the sake of benefits or costs. “For many people, biological diversity has an intrinsic value independent of its economic benefits,” says Uta Eser, who is a specialist in ethical issues related to biological diversity and runs an office for environmental ethics in Tübingen, Germany. The way we deal with biodiversity has a strong moral component. At “the heart of the Convention on Biological Diversity,” according to Uta, is justice for future generations, as well as for the people worldwide alive today who are mostly poor and suffer most from the consequences of the loss of biodiversity.

For more information  
on biodiversity  
research at WSL,  
see: [www.wsl.ch/  
biodiversity](http://www.wsl.ch/biodiversity)

## Include the human factor

WSL researchers work in this moral tension zone. “Biodiversity is not a fixed state, but a societal goal,” says Rolf. For example, you can maintain a meadow to promote rare species, or leave it alone to allow natural processes such as forest regeneration. It is up to the public and politicians to decide which goal is more desirable. “We researchers can then make recommendations on how to reach the goal and provide basic scientific information about the effects of certain interventions.”

WSL's biodiversity research began in the 1970s with inventories and the long-term monitoring of particularly valuable natural areas. To this day, WSL monitors – partly on behalf of the Federal Government – the development of bogs, dry meadows and pastures, floodplains, amphibian spawning sites and forest reserves. It also maintains the national databases for fungi and lichens (see page 8). Such monitoring enables the documentation of changes in populations and species and indicates where conservation measures are needed and how well they work.

But inventories alone are not enough. Environmental and living conditions are constantly changing, which means that the processes leading to the waxing and waning of diversity must also be understood. Can a structurally rich and diverse forest better withstand frequent storms? What effects do motorways have on the genetic diversity of dispersing animals? How have species adapted to habitats and how quickly can this take place, for example in response to climate change?

By answering such questions, WSL provides the authorities at the federal, cantonal and municipal levels with the information needed to select measures to halt the loss of biodiversity. WSL researchers also help to convince the public that something must be done through personal engagement and public lectures. Rolf believes that what is lacking is often not the knowledge about what needs to be done, but rather the political will to do something. Nature conservation needs money and space – and both are scarce.






Magnificent spots of colour along the edge of a rape field. The pressure on biodiversity is greatest in agricultural land.

The biologist therefore advocates more diversity in the management of biodiversity. Wherever possible, nature should take precedence and, for example, wilderness should be allowed or extensive farming encouraged to foster biodiversity. In other places, human recreation or land use may have priority. This ensures that habitats of all quality levels are available. Because: “Only diversity creates diversity.” *(bki)*





The 1-m<sup>2</sup> turf mats were packed into container bags and transported to the lower sites by helicopter.

The researchers removed the vegetation in some parts of the site at 1400 m a.s.l., replacing it with plants from 2100 m a.s.l. This should show how the plants from the higher altitude develop without competition from the vegetation growing at 1400 m altitude.





Researchers from WSL and ETH Zurich transplanted 80 turf mats growing at 2100 m above sea level to lower mountain meadows at 2000 m, 1800 m, 1600 m and 1400 m a.s.l. The experiment will show how different climatic conditions affect plants, soils, herbivorous insects and soil fauna.

Calanda near Haldenstein  
(Canton Grisons), 1400 m a.s.l.



## Out and about in the lichen forest. WSL employees are currently combing Swiss forests in search of lichens. Their data form the basis for revising the Red List of endangered lichens.

Michael Dietrich is using a magnifying glass to scan the bark of the tree, centimetre by centimetre. Although it is cold and foggy, he has spent the past ten minutes crouching beneath an impressive spruce. From time to time he carefully scrapes off a tiny piece of the bark with a knife and drops it into an envelope. After he's finished examining the tree, he moves on to the next one, another spruce. Michael is a lichen expert. By summer 2021, he and four other WSL employees will have searched 500 forest plots to find lichens. The plots are part of the National Forest Inventory's (NFI) network of permanent observation plots distributed across Switzerland. On each of the 500-m<sup>2</sup> plots – the size of about two tennis courts – experts carefully examine every single tree. “This can take a good five to six hours,” explains Michael.

About twenty years ago, Michael already surveyed the lichens in the same area. The data from this inventory was included in the first Red List of threatened epiphytic and terricolous lichens in Switzerland, published by the Federal Office for the Environment (FOEN) in 2002. Almost forty percent of the lichen species studied were classified as endangered at the time, a warning signal that the



Michael Dietrich is one of the five experts collecting field data for the revision of the Lichen Red List.



diversity of such inconspicuous organisms is also threatened. In the case of lichens, the organisms involved form a symbiosis consisting of a fungus and at least one green alga or a cyanobacterium. Even though they are mostly unspectacular, lichens provide habitats and nutrition for various animals and are excellent indicators of air quality. They are also indicators of forests that have been managed over a long period in a ‘close-to-nature’ way.

The Red List of lichens is currently being revised to find out how the frequencies of the species have changed since 2002 – and Michael is once again inspecting the steep mountain forest above Emmetten in Canton Nidwalden. Today, he is not, for a change, alone. WSL biologist, Silvia Stofer, who is coordinating the revision of the Lichen Red List at WSL, is accompanying him on this October morning. “I like to go along to the first fieldwork sessions when a new project starts so we can clear up any ambiguities in the data collection straight away,” she says. Michael calls her to tell her he has discovered something special. On the tree he is investigating, he has found small fruiting bodies growing at eye level. “Clearly *Lecanactis abietina*,” says Michael happily – the species is relatively rare in Switzerland.

After the fieldwork, Michael takes the envelopes with the pieces of bark to the WSL laboratory in Birmensdorf. Here Silvia and her colleagues analyse the lichens that cannot be determined with certainty in the field, as is the case with many of the 786 known epiphytic and terricolous lichen species in Switzerland. Silvia takes a piece of bark carefully out of an envelope and examines the lichen growing on it under the microscope. The identification of the species is anything but simple. “The size and shape of the spores or the



*Lecanactis abietina* grows on old coniferous trees in areas in the Pre-Alps with high precipitation and fog levels.

Photo: Christoph Scheidegger, WSL

shape of the tubes containing the spores often give clues as to the species,” says Silvia. To be able to identify a lichen, however, it must have fruiting bodies. If this is not the case, chemical analyses of its constituents can help.

### **Data centres combine research and practice**

Once the lichen species have been identified, all the data Michael recorded at the site where they were found – such as the habitat, microhabitat or size of the lichen population – are fed into the computer and thus into SwissLichens, the Swiss Centre for Information on Lichens at WSL. SwissLichens provides an overview of the distribution and frequency of all lichen species known in Switzerland and serves as a basis for determining the conservation status of the individual species in the Red List. The data is publicly accessible. “One of the aims of SwissLichens is to make information about the distribution, conservation status and ecology of lichens accessible to the general public,” says Silvia, who heads the data centre.

In addition to SwissLichens, WSL also operates SwissFungi, the National Data and Information Centre on Swiss Fungi. SwissLichens and SwissFungi are affiliated to InfoSpecies, the umbrella organisation of the national data and information centres for biodiversity. Not only is there a Red List for lichens, but also for macrofungi, i.e. fungi whose fruiting bodies are visible to the naked eye. It was published for the first time in 2007. Around one third of the species studied were classified as endangered at the time. This list is also due to be revised. Andrin Gross, head of SwissFungi, is currently clarifying which data collection methods should be used.

### **Sensitive organisms**

In addition to meticulously searching the NFI plots, the field teams also conduct exploratory tours in fourteen selected areas in Switzerland, each covering an area of 20 x 20 square kilometres. The aim is to find, in these areas, as many lichens that occur in rare habitats as possible. For example, some need warm, extensively managed meadows and others canyon forests.

Is the Red List of lichens longer or shorter than before? “We will find out when the data has been evaluated,” says Silvia. She assumes that there has been a shift in the frequency of species, as the influences lichens are exposed to today differ from those twenty years ago. At that time, issues such as acid rain were topical, but today the issues are climate change and the pollution of habitats with nitrogen. “Probably lichen species that are good at coping with nitrogen input from the air are more common today than they were twenty years ago,” she believes. The revised Red List will show how many of Switzerland's epiphytic and terricolous lichens are actually endangered or even threatened with extinction. It will be published in 2022.

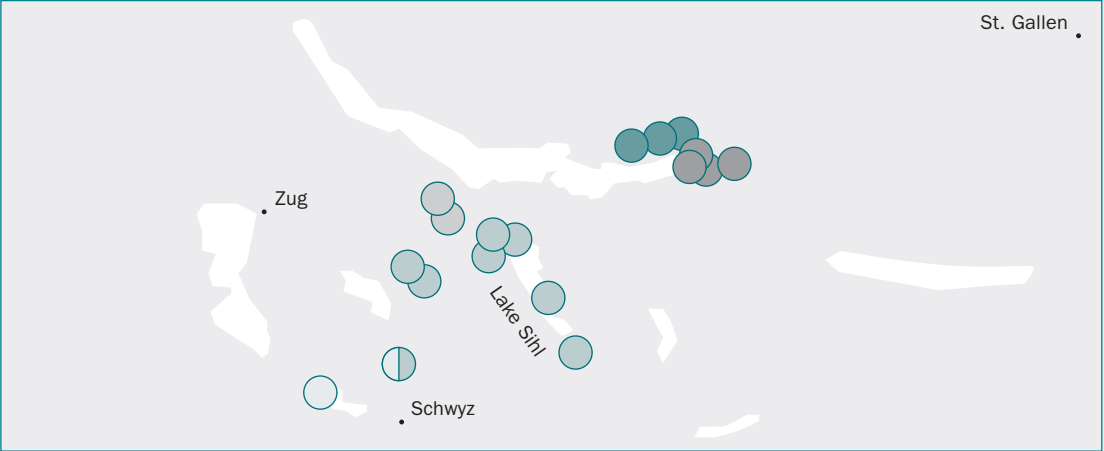
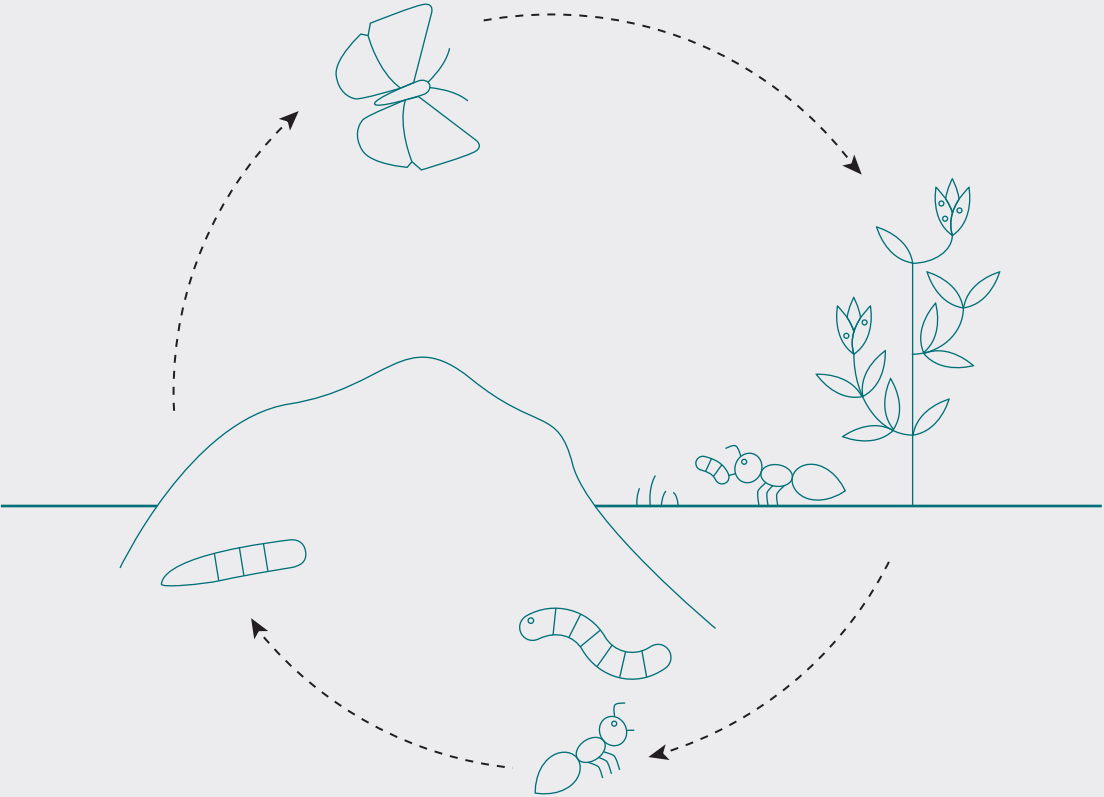
*(lbo)*

For further information on both the data and information centres at WSL, see: [www.swisslichens.ch](http://www.swisslichens.ch) and [www.swissfungi.ch](http://www.swissfungi.ch)



INFOGRAPHIC    The Alcon blue: conditions must be just right for the butterfly to fly

The Alcon blue (*Phengaris alcon*) occurs only in areas where one of the two species of gentian on which it lays its eggs grows, namely the marsh or the willow gentian. It also relies on one of two species of Myrmicine ants. The caterpillar deceives the ants with its scent into treating it as one of their own larvae. The ants carry the caterpillar into their dens, where they nurture it until it pupates and later emerges as a butterfly.



The Alcon blue flies only short distances. With the help of DNA analyses, WSL researchers are investigating whether Alcon blue butterflies from different populations mate with each other. It seems that only in the region around Lake Sihl does genetic exchange between populations occur. To conserve the isolated populations in the other regions in the long term, effective connectivity measures are needed.

# Leaf eater at work: Who plays what role? How much biodiversity does it take for an ecosystem to function? WSL researchers are investigating this by reconstructing nature in the laboratory.



Woodlice are scurrying through dead leaves in plastic tubes. In other tubes, earthworms are digging small tunnels in the ground, and some tubes have snails crawling up their walls. These creatures are part of an experiment that postdoc Simone Fontana and intern Yumi Bieri are performing at WSL under the direction of Marco Moretti. They have set up miniature habitats there, so-called mesocosms, in air-conditioned chambers. “We want to use these to investigate how changes in biodiversity affect ecosystems,” says Simone.

Specifically, the researchers want to know how the loss of species and changes in species composition affect the decomposition of leaves on the forest floor, the so-called litter. Invertebrates, such as woodlice, earthworms and snails, play an important role in this process. They eat leaves that have fallen to the ground and shred them. Smaller creatures, bacteria and fungi can then degrade the leaf bits further. In this way, nutrients from the dead leaves are returned to the soil, where plants take them up through their roots and use them for growth.

Litter decomposition thus plays an important role in the forest ecosystem, with different species performing different functions. However, climate change and other human influences are reducing species diversity worldwide. “As a result, important functions have been lost in many ecosystems,” says Simone. He wants to find out whether this is also the case with the decomposition of



Postdoc Simone Fontana watering the miniature habitats in which he is studying how earthworms, snails and woodlice decompose leaves.



leaves in forests. Does decomposition still work if one or more species are missing? And what role do the individual species play in the system?

Simone hopes to answer these questions with the help of mesocosms in the laboratory. The complexity of nature cannot be simulated in such mesocosms, but this is not the goal. “The advantage of lab experiments is that the individual factors in the system can be easily disentangled.”

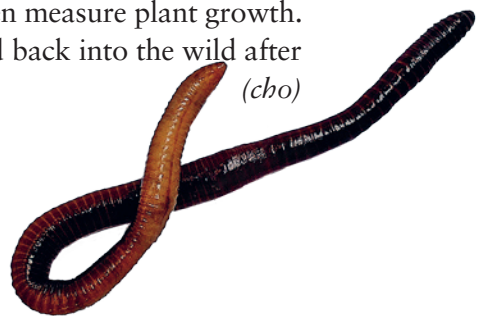
This is exactly what the postdoc is doing. He first reduces the complexity. In each of the 189 mesocosms – sections of drainpipes 30 cm high – he places only one animal species, i.e. one of each of the three snail, earthworm and woodlice species. “This enables us to find out how much foliage each species decomposes on its own,” says Simone. The pipes are filled with a layer of soil 20 cm deep, with exactly 5 grams of leaves on top. The leaves are birch, maple or equal proportions of both tree species.

### Who eats how much?

If, several weeks later, about half of the leaves have been decomposed, Simone and Yumi finish the experiment and weigh how many grams each species has eaten. This information then serves as a basis for the researchers to gradually increase the complexity in further experiments and combine two or more species or animal groups. One question is whether their total foliage consumption is more when the different species are together than could be expected from their individual consumptions combined. This phenomenon, known as complementarity, often occurs in ecosystems where species complement each other in performing a given function. If a species disappears, it may lead to a function no longer being performed.

In the experiment, the species of a group of organisms are chosen to differ in size as much as possible and/or have different habitat and feeding preferences. “This makes it more likely that they will be complementary, i.e. complement each other,” says Simone. He was able to observe this in earlier experiments with large and small individuals of the same woodlice species. It will also become apparent whether litter decomposition is slower with just one or a few species. “If this is the case, the disappearance of species could cause problems for the forest ecosystem.” If there is a delay in nutrients returning to the soil, it may take longer for plants to germinate and grow. This is something the researchers also want to investigate, which is why, at the end of the experiment, they will take soil from the mesocosms to sow seeds in and then measure plant growth. The experimental animals themselves will be released back into the wild after the experiment.

For more information  
about the miniature  
habitats, see:  
[www.wsl.ch/  
leaf-eater](http://www.wsl.ch/leaf-eater)



(cho)



## Habitat map of Switzerland. Switzerland is home to many different habitat types. A digital map, produced at WSL in a pilot project, provides an overview.

Fields, lakes, glaciers, forests, and even parking lots make up some of the over 200 different types of habitat found in Switzerland. These habitats are constantly changing, whether as a result of natural processes, such as the flooding of alluvial forests, or human intervention, such as new roads.

Our requirements for space have risen sharply and human interventions in the landscape are increasing. These trends impact, in particular, the habitats



The map on the left shows the colour-infrared ortho aerial image, and the map on the right the classification of the adjacent area into different habitats.

of plants and animals, and thus the basis for species diversity. Understanding such developments increasingly raises questions such as: Where do particular habitats occur? Which habitats are expanding? Which habitats are disappearing? Up until now, there has been no overview of the spatial distribution of either natural or human-influenced habitats in Switzerland. The OECD criticised this situation in its 2017 Environmental Review Report and recommended developing a habitat map for the whole of Switzerland. The Federal Office



for the Environment (FOEN) therefore commissioned WSL to carry out a pilot study.

Such a digital map cannot, of course, be produced at the touch of a button. Project manager Christian Ginzler and his team initially collated national geodata, such as vegetation height models, digital terrain models and time series of satellite images. They combined these to obtain information on the different types of habitat. The project team relied on the existing classification of habitats according to Delarze and Gonseth, the most commonly used classification in Swiss biodiversity research, which classifies habitats according to the composition of plant species into plant communities. “This systems poses major challenges,” says Christian, “since individual plants cannot be identified using remote sensing data.”

### **Prototype will be adapted to needs**

One finding from the pilot study was that the level of detail in the map is limited. At the highest habitat classification level, nine classes, such as forests, water bodies and grassland, can be mapped well. Some habitat classes can be mapped in more detail. For example, the map can distinguish between standing and flowing water. However, the more detailed the habitat subclasses are, the more difficult it is to represent them. For example, different grassland habitat subclasses are difficult to differentiate, and habitats that are almost vertical, such as rock faces, or underground, such as caves, cannot be identified at all.

Experts and future users, such as FOEN staff or cantonal conservation officers, will be able to test the prototype in a workshop. The needs of the users will be taken into account. “If, for example, it is crucial for users to be able to distinguish oak from beech forests, we will work with FOEN to clarify what needs to be done to obtain this level of detail,” says Christian. *(sni)*



**Act before it is too late.** Biodiversity is in a bad state. What can research and/or politics do to improve it? Silva Semadeni, a member of the Swiss National Council, and biologist Niklaus Zimmermann discuss topics ranging from the value of nature, land-use changes and the Enlightenment. Their conclusion: we know enough to act now!

**You are committed to biodiversity. How did that come about?**

**S:** As a child, I spent every summer on the alp. My grandfather was a teacher and farmer, as well as a great nature lover. He introduced me to fire lilies and edelweiss, and taught me how to observe nature. This has stayed with me, and explains why I am a conservationist.

**N:** My mother was interested in plants, and we went hiking a lot. At high school I had a very good biology teacher who was able to nourish our wonder at the 'miracle' of nature.

**In everyday life do you notice that the state of biodiversity is deteriorating?**

**S:** Yes, definitely! We used to observe red-backed shrikes, frogs and tadpoles on the alp. Today I don't see them any more. And everywhere in the country new buildings are going up where natural open spaces used to be.

**N:** I find that difficult, many things happen slowly and secretly. But a few years ago I was in Montenegro, where I noticed an unbelievable abundance of insects. I don't remember exactly what it used to be like here, but I have the impression that there

used to be more horseflies and mosquitoes.

**Can you explain these developments?**

**N:** Changes in land use play an important role, with the intensive use of fertilizers, herbicides and pesticides. A second factor is the pressure from invasive species that displace native animals and plants. This pressure is increasing with climate change.

**S:** Intensified agriculture is a major problem. Biodiversity does not have priority despite so-called 'biodiversity subsidies' and the need to demonstrate 'ecological performance'. Take, for example, the presence of small-scale structures – under certain forms of direct payment you are even rewarded for clearing them. There are also too few protected areas, and those that we have are not maintained well enough. The FOEN has shown that it requires an initial CHF 1.6 billion to restore them, and then an annual 80 million francs to keep them in good shape. With the 'Biodiversity Action Plan' we have increased the finances a little for once, but that is not enough. And I'm always afraid that the funds for the environment will



The historian Silva Semadeni is a member for the SP Party of the National Council from Canton Grisons. She was President of Pro Natura Switzerland until 2018.



Niklaus Zimmermann is a biologist who worked in the Inter-governmental Platform on Biodiversity and Ecosystem Services (IPBES). He is a member of the WSL Directorate.





For further information on the Action Plan Biodiversity, see: <https://bit.ly/2Dn9pfl>

The protection of biodiversity can be justified not only from the point of view of values, but also economically. Biodiversity benefits people, for example by pollinating crops.

be cut in the annual budget debate. It has no political priority.

### Why should it be a priority?

**N:** Actually, it's about a legacy: we want to pass on our earth as we found it, and not in worse shape. But there are also economic aspects. In America, for example, certain agricultural regions have been

cleared to such an extent that pollination no longer works. This leads to huge crop losses. But I find the economic arguments dangerous: if an individual species disappears, it does not necessarily lead to economic damage. Such a loss would be considered acceptable if you think purely in economic terms.

**“Scientists should make clear statements and not always relativize everything.”**



**s:** The first approach, the legacy, appeals to me much more. But many politicians see only the economic aspects.

**What would it take for politicians to become more active in protecting biodiversity?**

**s:** With the current composition of our Parliament, only pressure from the public can help. We must start initiatives. Civil society must be the driving force behind politics.

**Should we also do more research?**

**s:** Science should show alternatives, for example to dangerous pesticides. After all, do farmers really enjoy using harmful pesticides?

**n:** For me education is very important. We should research what we do not yet understand. But we do know enough to be able to act now. We scientists must also make our results more accessible to the public in order to counteract the impression that scientific results are arbitrary and trivial.

**s:** Exactly. The transfer of knowledge is central. In my experience, science has a real credibility problem. I find that dramatic.

**n:** The whole development that we have gone through since the Enlightenment is based on the use of logic and argumentation – and now certain circles are questioning that. They simply make claims about whatever they want! For me, this is like stepping back into the Middle Ages, when what was preached from the pulpit specified what was true and what was false. However, science must not be misused for statements that are too dramatic, otherwise it can be

disputed. This is what happened with the debate about forests dying a few decades ago. Then people said: “The forest is still standing, so you can't believe science.”

**s:** That's not quite true! Steps were taken to reduce acid rain, and the catalyst converter was quickly introduced. Scientists should make clear statements and not always relativize everything.

**Politicians also like to remain vague. For instance, the ‘Biodiversity Action Plan’ postpones concrete measures to a second implementation phase starting in 2024. Will that be too late?**

**n:** The longer we wait, the greater the irretrievable loss. In waiting, we run the risk that further ecosystem functions will be impaired. At the same time, it is estimated that only 20 percent of the world's species have been described, which I find both fascinating and frightening. It means we will lose many species before we've identified them, and before we know anything about their distribution, their ecology, and their contributions to ecosystem services.

**s:** What is worse than the delay is that even when steps are finally taken, they will not be very concrete and will have little effect. Drastic measures are needed, and people must accept that there are limits. It is not only politicians who find this difficult! *(bio)*

For further information on IPBES Switzerland, see: <https://bit.ly/2TN-6S4y>



A woman with reddish-brown hair, wearing a blue t-shirt, brown cargo pants, and orange sneakers, stands on a rocky outcrop. She is looking off to the side with a slight smile. The background is a lush green forest of tall evergreen trees, with a snow-capped mountain peak visible in the distance under a clear sky.

Jeannette Nötzli, Davos

“You can get to the Sertig Valley very quickly from Davos, but still feel far away from the tourist hullabaloo. In winter I come here to go on ski tours, and in summer to go biking and hiking with my children. I feel most comfortable above the timber line, where the view is clear.”

#### PERMAFROST UNDER CLIMATE CHANGE

The geographer, Jeannette Nötzli, manages the PERMOS measurement network. This records changes in the permafrost – permanently frozen soil – in the Swiss Alps. It includes automatic measurements of temperatures in boreholes up

to 100 metres deep. “The data is important for finding ways to deal with natural hazards in the mountains,” says Jeannette. Climate change is causing increasing warming of permafrost, which can make steep mountain slopes unstable.



## FORESTS Ash dieback: Not all affected trees show symptoms



A fungus (*Hymenoscyphus fraxineus*) attacks and often kills shoots and branches in the crowns of ash trees.

It is tiny, but its effect is devastating: the ash dieback pathogen, *Hymenoscyphus fraxineus*, attacks the Common ash (*Fraxinus excelsior*), causing its shoots to die. The pest is a fungus that was probably introduced into Europe from East Asia in the 1990s with imported ash plants. Since then it has spread epidemically, also in Switzerland. More than 90 percent of all ash trees in Switzerland are infected, and many have died.

The fungus forms its fruiting bodies and thus its spores on ash leaves on the ground. It is impossible to remove it from the forest. But ten

percent of Swiss ash seem to be resistant to the pathogen, or at least to tolerate it. This is where research comes into play. When Swiss Forest Protection, whose office is based at WSL, asked foresters to identify healthy trees, 397 ash trees were reported. Specialists from an environmental engineering firm inspected these trees in 2018 and recorded various data on the sites where they were found, such as regeneration, the forest communities and the density of the ash trees. The aim is to find out why these trees are resistant to the fungus.

“There are certainly more healthy ashes than the 397 trees reported. But it is difficult to identify them in a stand where many of the ash trees are diseased,” explains Valentin Queloz, Head of Swiss Forest Protection. The ash trees found are now being tested further in the laboratory. Genetic analyses could shed light on why some ash trees are susceptible to the fungus and others are not.

While researchers are eagerly looking for solutions to the ash dieback, practitioners are also challenged. “The still healthy ash trees should be spared and the ash regeneration under these trees should be given enough light to have a chance at all,” says Valentin. The future of the ash in the Swiss forests may depend on these trees. (lbo)

[www.waldschutz.ch](http://www.waldschutz.ch)

## FORESTS Data series up to 130 years old provide answers for tomorrow's forests

“To create a sound basis for forestry to its fullest extent” was the mission given to the predecessor of WSL, the ‘Central Station for Experimental Forestry’ in 1885. From the outset, this included researching open questions on the development and management of Swiss forests and communicating the findings to forestry practitioners.

To fulfill this mission, WSL still carries out numerous series of experiments on the growth of the most common tree species and forest types. It operates 390 permanent plots in Switzerland, covering a total area of 132 hectares, which is about as large as 180 football pitches. Researchers measure the growth in trees’ diameter and height, and record dead individuals and the intensity of silvicultural interventions. The plots represent very different types of for-

est: most on the Central Plateau are covered with beech and Norway spruce, and others with oak; chestnut trees dominate in the Southern Alps; while larch and Swiss stone pine trees are more common in the higher mountain areas.

In the Pre-Alps and the Jura, the WSL collects data from so-called ‘plenter forests’ (literally ‘plent forests’), in which foresters regularly harvest only a few of the largest trees. “The data set, which is more than 100 years long, is one of the most valuable in the world for such mixed forests,” says David Forrester, a researcher in the Research Group ‘Stand Dynamics and Silviculture’. The findings from this research help foresters and forest owners to optimally control the incidence of light in plenter forests, in which tree species that need light, such as Norway



Jens Nitzsche, a technical assistant in the Research Group ‘Stand Dynamics and Silviculture’, measures the stem diameter of a Douglas fir on a permanent plot.



spruce and beech, and those that are shade-tolerant, such as silver fir, both grow.

### **A treasure trove for answering new questions**

“Our long-term data series, obtained from more than 450,000 individual trees, show how trees react to external influences,” says David. This enables researchers to inform foresters about, for example, which tree species mixtures are most suitable for producing high-quality timber and ensuring that forest management is sustainable and as close to nature as

possible. Or they may explain where and how mountain forests provide protection against avalanches and rockfall. “The impact of climate change on forests managed in different ways is a typical example of an environmental change that raises new questions for forestry,” says David. (rlä)

[www.wsl.ch/forest-growth](http://www.wsl.ch/forest-growth)

## FORESTS Natural forest reserves: High species diversity of insects and fungi thanks to deadwood



The Least stag beetle (*Sinodendron cylindricum*) is a smaller relative of the well-known Stag beetle.

When a tree dies, it comes alive. What looks dead from the outside is a valuable habitat for hundreds of species of insect, fungus and bacteria. Some of these organisms, such as the larvae of Longhorn beetles or the rare Least stag beetle (*Sinodendron cylindricum*), use deadwood just as a place to develop. Others tear down the supporting walls of their homes by

breaking down lignin or cellulose. Insects thus not only promote the decomposition of deadwood, but also recycle nutrients.

Deadwood can be found in every forest, but it is especially frequent in the 724 natural forest reserves of Switzerland. There nature is in command. Humans do not intervene. Such forests are generally regarded as species-rich, but are these protected areas really more diverse than forests that people maintain and exploit? So far, hardly any reliable data on this topic exists in Switzerland. This is why researchers from WSL and the School of Agricultural, Forest and Food Sciences HAFL in Bern began looking into this question in 2017, focusing on deadwood colonised by fungi and insects as an example.

In a four-year project, they have so far investigated four beech forest reserves and compared them with managed beech forests. In each for-

est, they concentrated on 11 plots, each with two 500-m<sup>2</sup> sub-areas containing at least one large piece of a standing or lying dead stem or rootstock. On each sample area, they collected fungal fruiting bodies and took samples from the decomposing wood to identify the fungal flora through DNA analysis. They also set up an insect trap, which they emptied six times a year, next to the largest piece of deadwood.

**Rare species trapped**

The beech forests in the Natural Forest Reserve Josenwald near Walenstadt in Canton St. Gallen contain almost a hundred cubic metres of deadwood per hectare and are prime examples of habitats with a wealth of deadwood. Although not all the insects caught there have yet been identified, insect expert Beat Wermelinger has already reported unusual findings: “We found a very rare Flat bug, which has only been observed twice in Switzerland.” Rare insects, such as the Stag beetle and a *Rosalia longicorn*, have also both been spotted.

In the beech forest reserves Sihlwald ZH, Combe Biosse NE, Tariche JU and Josenwald SG, the mycologist Stefan Blaser has so far identified 304 species of fungi, compared with only 267 in the nearby managed beech forests: “We found six highly endangered and 23 endangered species in the reserves, but only half as many in the commercial forest. This finding indicates that the living conditions for deadwood fungi are better in natural forest reserves than in commercial forests.”

The researchers are keen to find out what they will discover during the next two years when they explore species diversity in eight more forests.



Flying insects are caught in so-called cross-window traps.



The Brick cap (*Hypholoma sublateritium*) grows on rotten rootstocks, stems or deadwood from deciduous trees.

“The data so far shows that forest reserves containing a lot of deadwood provide an important refuge for species diversity,” says Stefan Blaser happily. (rlä)

[www.wsl.ch/monitoring-natural-forest-reserves](http://www.wsl.ch/monitoring-natural-forest-reserves)

Photos: Beat Wermelinger, WSL; Max Danz



# Wild areas: Where nature can have free rein

There really are places in Switzerland where nature has the say and humans hardly play a role. The wildest and most untouched areas can be found around the highest peaks and glaciers, for example in the Aletsch re-

gion or in southern Valais. If wilderness is defined less strictly, remote Alpine valleys – especially in the Grisons and Ticino – can also be considered wild regions. These areas are surprisingly large: they account for



It is particularly in the mountains that wild places can still be found, e.g. the 'Chluse' Gorge in Gasterntal above Kandersteg.

Photo: Markus Bolliger

10 to 15 percent of Switzerland's total surface area. This is the conclusion of a study carried out by WSL researchers on behalf of the Alpine conservation organisation, Mountain Wilderness. It is the first systematic mapping of wilderness in Switzerland, initiated and financed by the Bristol-Stiftung.

'Wilderness' can be defined as natural areas without significant infrastructure, economic use or other human impact. Numerous animal and plant species depend on such areas because they cannot find suitable habitats in cultivated landscapes. The shy lynx needs large, untouched forest areas, while many beetle species breed exclusively in large dead trees, which are rare in commercial forests (see page 22). In order to identify such wild areas in Switzerland, the researchers used four criteria for mapping them: naturalness of land cover, extent of human influence, remoteness and ruggedness of topography, i.e. rock faces or mountain peaks.

### **The public are somewhat critical**

When the map is created in this way, unused natural spaces appear in many places. But preserving or even enlarging them is not conceivable without the support of the public. In cantons with high wilderness potential, the researchers responsible for the social science part of the study surveyed locals and experts to find out what they thought about letting nature develop freely. The result is striking: in places where the potential for leaving nature untouched is greatest, the population is critical of the idea of letting nature have free rein. The people there stated that they had a strong attachment to their

homeland and to nature. They fear 'their' landscape will change greatly, and that they may also face disadvantages because of restrictions on use, an increase in natural hazards or the loss of traditions such as wild hay-making.

### **The potential of wilderness in Switzerland**

Precisely because it takes both the geographical and social dimensions into account, the study shows for the first time where the potential for wilderness in Switzerland is greatest – especially in high mountain regions. Most of the areas with the greatest wilderness potential overlap with large parts of today's protected areas, but not all are in such areas. Conversely, protected areas are not always located in the wildest places. Zurich's Wildnispark Sihlwald, for example, does not score particularly high on the criteria for wilderness used in the study – but it is nevertheless a small wilderness in the agglomeration of Zurich that the local population and the City of Zurich both want and appreciate. For Mountain Wilderness, the study shows that the local population need to be made more aware of the topic and the public involved more. "Only an increased acceptance of wilderness will open the doors to its protection," the organisation concludes. *(bki)*

[www.wsl.ch/wilderness](http://www.wsl.ch/wilderness)



# Calculating pedestrian flows to optimize walking routes

Having a forest within walking distance or a footpath along a watercourse makes a residential area more popular and encourages local people to go out for walks or jogging. Local councils want to provide their citizens with an attractive environment to live in, which includes having easy access to local recreation areas, with no barriers in the way that make access difficult. A new WSL computer model simulates pedestrian flows between residential and local recreation areas and thus helps to determine the effects of improving walking routes.

The model is a so-called agent-based model that represents the decisions of individuals. Each agent represents a person walking from their home to an attractive local recreation area and back again. At each crossroads, the agent decides how to proceed. The criteria for deciding include the nature of the route, i.e. whether it is a path, a gravel track or a tarred road, as well as aspects of landscape quality, such as whether there is a beautiful view or a water body.

In the model, the researchers calculated various decision strategies: the shortest or most scenic route, a combined route and a purely random choice. For each strategy, the agent-based model was run 100 times. The results show what effects certain upgrading measures have. Such measures include building a pedestrian bridge or an underpass under the motorway, shortening access paths to an attractive stretch of water or forest, or resurfacing tracks with natural material. The model thus helps the local authorities to prioritise planned measures. “Having more attractive

and shorter paths with many natural features also attracts people from more distant neighbourhoods,” says project manager Silvia Tobias, who developed this method as part of a Swiss federal pilot project for sustainable spatial development.

The researchers conducted a survey to find out how well the model matches the decisions made by real recreationists. Locals in Wil (SG) plotted their walking and jogging routes on maps. The model corresponds with the paths chosen in reality quite well and thus provides communities with plausible indications as to whether it is worth removing certain obstacles. The researchers applied the model to the Glattpark region on an experimental basis and compared it with survey results there. “We came up with results giving routes comparable with real walking paths,” says Tobias. It seems, therefore, that the agent model could, in principle, be applied to all towns and suburbs in Switzerland. *(bki)*

[www.wsl.ch/pedestrian-flows](http://www.wsl.ch/pedestrian-flows)



Hajar Hoseyni, Birmensdorf

“Lake Rumen near Küsnacht is a special place for me. After my arrival in Switzerland, I lived near here and often came to this lake with colleagues for a barbecue.”

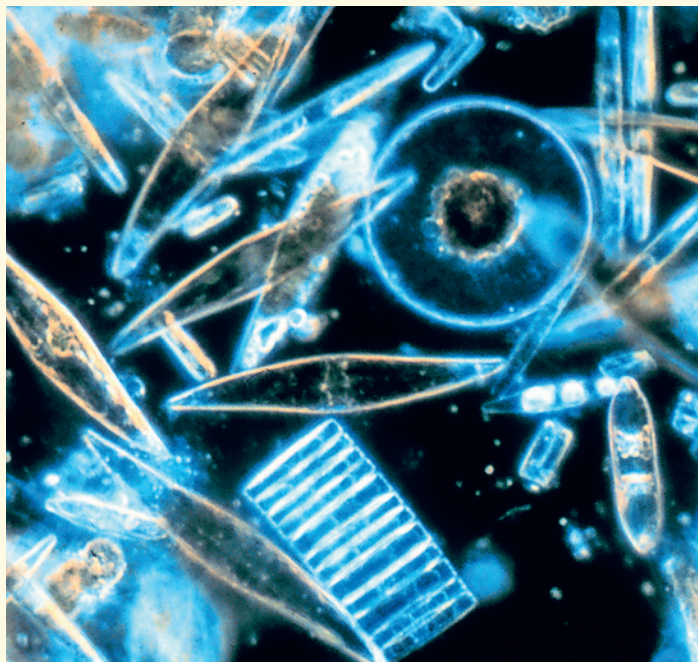
#### THE COMPUTER AS A STEPPING-STONE

If the phone doesn't work or a computer needs an update, this is where Hajar Hoseyni comes in. The Afghan Hajar Hoseyni has been doing a four-year apprenticeship in computer science and systems engineering at WSL since August

2017. “I like programming best,” says Hajar. At the age of 13 she got her first PC and taught herself how to use it. Hajar fled to Switzerland in 2012. Thanks to the apprenticeship, she now has a permit to stay.



## BIODIVERSITY Tiny giants of the oceans: Global map shows the species distribution of phytoplankton for the first time



Diverse shapes: diatom algae make up a large proportion of the marine phytoplankton.

Despite their microscopic size, planktonic organisms have a big impact on the biosphere: photosynthetic plankton in the oceans produce more oxygen than all the rainforests combined. They bind large quantities of CO<sub>2</sub> and provide the basis of life for many marine animals. But the warming of the oceans could reduce the productivity of plankton. It is unclear whether species diversity will also decline. “Up until now, we didn't even know how phytoplankton species are distributed in the oceans,” says Damiano Righetti, a PhD student in the Environmental Physics Group at ETH Zurich.

He has therefore developed, together with WSL researcher Niklaus Zimmermann, a method to map the spatial and temporal distribution of phytoplankton species. He collected

more than half a million data measurements for 536 different species from various databases. Using a computer model, he created the first map of their global diversity patterns.

The result: the total number of plankton species decreases from the equator to the poles. This phenomenon is known from terrestrial species, but unlike for them, for plankton species the decrease is not continuous. Between the 35th and 55th latitude, the diversity is significantly lower than would be expected, before increasing again towards the poles. The marked dip in mid-latitudes could be due to the harsh and seasonally changing environmental conditions prevailing there, the researchers suspect.

Thanks to the new model, it has been possible to derive the biodiversity patterns of phytoplankton from very incomplete and unevenly distributed data. “These mostly originate from seawater samples collected along the normal shipping routes. There is hardly any data available from less frequented areas,” says Damiano. The model can be used to correct for uneven sampling density, and also enables predictions to be made about how the biodiversity of the phytoplankton will change if sea temperatures continue to rise. (cho)

[www.wsl.ch/phytoplankton](http://www.wsl.ch/phytoplankton)

When dawn breaks, they leave their daytime roosts and go out foraging. Bats often travel long distances to their hunting grounds on water bodies, along forest edges or in orchards. They regularly use the same flight corridors in the landscape going along hedges or other structures, including house facades, that they can detect with their echolocation ultrasound calls. But where exactly the animals fly is often not clear, although this would be important to know so that their flight paths can be protected – especially in places where many bats have to fly through confined spaces.

Until now, detecting such corridors has been complicated and is only possible with extensive use of bat detectors or radiotelemetry, in which individual animals are equipped with transmitters. A simulation model developed by WSL researchers in cooperation with partners and on behalf of the Swiss Federal Office for the Environment, FOEN, now simplifies the search. For the model, the researchers recorded the calls of two bat species while they were commuting to foraging areas from six different roosts each. By combining these with geo-data on the areas, they were able to estimate how the animals move around in the landscape.

The model still has errors. “So far, we have not been able to include artificial light at night in our calculations because high-resolution data is, unfortunately, still not available for Switzerland,” explains project manager Martin Obrist. Bats avoid artificial light and shun street lamps, for example. In such cases, the model’s

predicted routes may not correspond with the actual flight corridors observed by a bat expert or a local monitoring observer.

In a follow-up project, the light data for various locations will be col-



The Greater mouse-eared bat (*Myotis myotis*) is one of the two bat species whose routes were followed by the researchers to develop the simulation model.

lected and integrated into the model. In addition, WSL modelling specialist, Klaus Ecker, is calculating flight corridors for a further 200 bat roosts of four target species for bat protection in Switzerland. The resulting data will be evaluated by a team of specialists to decide what measures to recommend to the cantons and planning authorities. (lbo)



# Climate change: Does extreme weather cause more damage?



Many buildings were damaged during devastating floods in 2005, such as here in Klosters, in the Grisons.

A landslide and subsequent debris flows severely damaged the village of Bondo in the Grisons at the end of August 2017. Experts assume that such events will become more frequent due to climate change. The IPCC panel members say that the economic costs of extreme weather events have very probably already increased worldwide. This is reason enough for geographer Norina Andres to try to find out whether climate change has led to an increase in damage due to extreme weather in Switzerland.

Norina is responsible for the Swiss flood and landslide damage database, which is maintained by WSL and financed by FOEN. It has collected records of damage caused by floods, landslides and debris flows during the past 47 years. At first glance, the data seem to confirm the assumption that the cost of damage is increasing. However, is this really

a consequence of climate change? As Norina says: “Nowadays everything is more expensive. People have more possessions, houses are more valuable and there are simply more buildings and other infrastructure.”

## Reassessed to account for the conditions prevailing today

In order to take into account the influence of such socio-economic and demographic effects, the researcher and her colleague, Alexandre Badoux, have used three different approaches to process the damage data. “This enables us to estimate what damage events that happened many years ago would cause under today's conditions,” explains Norina. For her calculations, she used first the development of the gross domestic product, then the increase in the real income of the population and finally the building insurance values, taking in-

flation and population development into account. “When we normalize the data like this, then we can see that the damage has not increased.”

Norina emphasises that her study does not call into question the existence of climate change. But in Switzerland it has not (yet) had a demonstrable effect on the amount of damage caused by floods, landslides

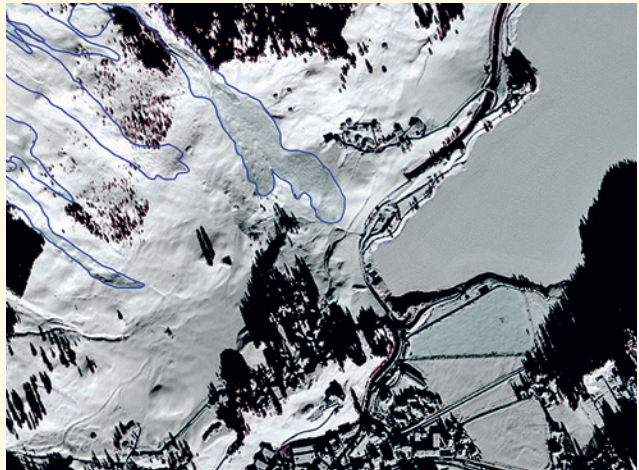
and debris flows. On the other hand, inflation, and the development of the population and prosperity play a role. Switzerland is also investing a lot of money in protective measures. “Perhaps these measures can counterbalance any climate change effects,” Norina speculates – which would be really good news. *(bio)*

## NATURAL HAZARDS      Avalanches detected for the first time with satellites over extensive areas

Lots of snow and lots of avalanches: this is what it was like in the Swiss Alps during the winter 2017/2018. During the heavy snowfalls in January 2018, the SLF issued the highest avalanche danger level warning, 5 (very high), for widespread areas in the Swiss Alps. At this danger level, many very large and extremely large spontaneous avalanches can be expected.

Up to now, information on avalanches that have occurred has come from observer reports or helicopter overflights, but for some areas no information is available. Some of the avalanche outlines have been digitized on the basis of photographs, but often only the number and size of the avalanches in an area have been recorded.

In January 2018, SLF researchers were able to use optical satellite data for the first time to document avalanche activity. The images cover an area almost one third the size of Switzerland. Elisabeth Hafner from SLF used the photos to map the outlines of all avalanches in the areas where the highest danger level prevailed, as well as in adjacent areas, recording a total of 18,737 individ-



Satellite image of Davos village with Lake Davos. The run-off areas of the village mountain and Salezertobel avalanches can be seen in the top left corner of the picture (outlined in blue).

ual avalanches. “The areas in the shade were a challenge in the satellite images. So too were wind structures in the snow, which can look similar to avalanches,” Elisabeth says. Despite these difficulties, no avalanche period has ever been recorded so completely and accurately before. The data is valuable because it allows avalanche warnings to be checked after the event to see whether the assessment of the avalanche danger was correct. The data is also used to validate danger zones and for research purposes. *(sni)*



## SNOW AND ICE Arctic Ocean: Spectacular expedition with the icebreaker ‘Polarstern’

The layer between ice and snow is thin – only a few millimetres thick. To investigate it, a team led by snow researcher, Martin Schneebeli, is spending the coming winter on the icebreaker, ‘Polarstern’, of the Alfred Wegener Institute. In the autumn, the ship will let itself become attached to the ice as part of an expedition north of Norway. There it will drift for a year through the Arctic Ocean, passing close to the North Pole, before being released North-East of Greenland in the summer of 2020. Martin will investigate the thermal conductivity of sea ice covered with snow. It describes how well the sea and the air are insulated from each other, which is important for estimating how the glaciation of the Arctic Ocean is changing under climate change.

Today we know that snow-covered ice insulates much better than

could theoretically be expected. Researchers have found a possible explanation in the cold laboratory in Davos. “In the experiment, a very thin layer was formed, consisting almost entirely of air, between the ice and snow. It massively reduced the heat flow,” explains Martin. During the MOSAiC expedition, he will now regularly collect snow-ice samples and analyse them with a computer tomograph. The reason why the scientist will be on the expedition is that he is keen to see whether he will also find this thin layer in a natural environment. *(bio)*

[www.slf.ch/expedition-en](http://www.slf.ch/expedition-en)



From autumn 2019 to summer 2020, the ‘Polarstern’ will allow itself to become frozen in the ice of the Arctic Sea and drift close to the North Pole. On board, some SLF researchers will also be conducting an experiment.

## SNOW AND ICE      GPS sensors measure how much water is stored in snow

Snow is an important water resource. To find out how much water is stored in a snowpack, researchers measure the so-called snow water equivalent (SWE). This value is needed, for example, to predict the amount of melt water in spring, but it is difficult to determine. Up until now, measuring it automatically has required large and expensive devices.

Researchers from Ludwig Maximilian University in Munich and the University of Natural Resources and Life Sciences in Vienna, together with SLF researchers, have developed a new method for measuring SWE simply and cost-effectively using conventional GPS sensors. To test it, they installed two GPS antennas on the SLF test site at Weissfluhjoch above Davos. The one on the ground got buried in snow during the winter. The other, on a mast, remained snow-free and served as a reference. If the GPS signal passes through the snow cover, the characteristics of the signal change. It becomes weaker and slows down. The researchers were able to calculate the SWE from the difference between the signals received above and below the snowpack. In addition, it was possible to derive the snow depth and liquid water content of the snowpack.

“For the first time it was possible to measure all three parameters using just one method,” says SLF Director, Jürg Schweizer. The values obtained correspond well with those from conventional reference measurements. Thus GPS sensors may one day be used to measure the three snow parameters in many different places quite cheaply. But before the



A researcher checks the GPS sensor installed on a mast in the Weissfluhjoch test site near Davos.

new method can be put into practice, it needs to be further tested and improved. This is why the researchers are now carrying out further measurements at three additional sites located between 815 and 1520 metres above sea level. *(cho)*



Marcus Schaub, Birmensdorf

“I enjoy the peace and quiet here on the shores of Lake Zurich, with the water and the view. When visibility is good, the mountains seem close enough to touch from Enge harbour. At the same time, the busy city is close by and has so much to offer – what a magic place!”



#### HOW DOES OZONE AFFECT FORESTS?

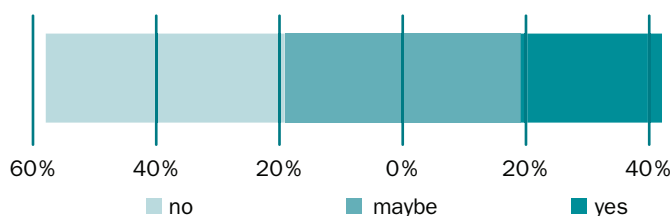
Pollutants or stress factors, such as extreme drought, can damage the forest. Ecophysiologicalist Marcus Schaub is investigating, among other things, how ozone influences the growth of trees under changing climatic conditions. He uses data

from the European monitoring programme 'ICP Forests'. "Together with our national and international partners, I am committed to ensuring that this data is widely accessible and can be used efficiently."

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## EDITORS' SURVEY

In the 1/18 issue of Diagonal, we asked how you use our magazine and what we could do better. We were particularly interested in finding out whether our readers like the print form or would prefer an electronic version of Diagonal. The result was clearly in favour of the print version:



Responses to the question: "Would you read Diagonal even if it were only available electronically?" were: 39% "no", 38% "maybe" and 23% "yes".

What is also in favour of the print version is the fact that each issue of Diagonal is read by, on average, two people.

The scope and frequency of publication were rated positively, with over 90 percent of respondents quite liking or really liking the design of Diagonal. A total of 462 people took part in the survey. Thank you very much!

The complete results of the survey can be found on the WSL website: [www.wsl.ch/diagonal-survey](http://www.wsl.ch/diagonal-survey)

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## OUTLOOK, DIAGONAL NO. 2, 2019

Focus of the next issue: From research to practice – from practice to research.

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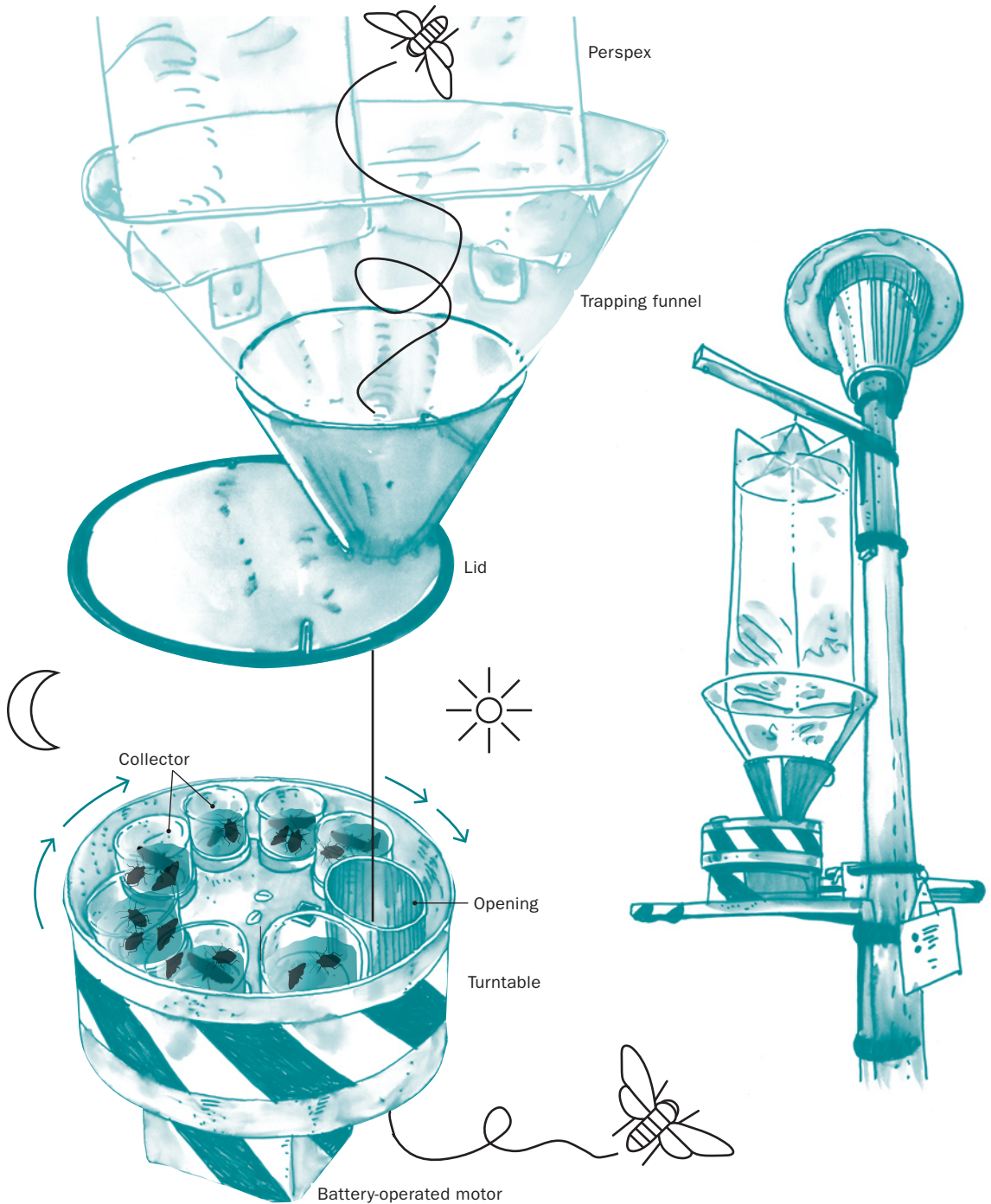
## PEOPLE



The WSL editorial team, from left to right, top row: Sandra Gurzeler, Birgit Ottmer, Beate Kittl, Claudia Hoffmann; bottom row: Reinhard Lässig, Sara Niedermann, Lisa Bose



## AUTOMATIC INSECT TRAP



WSL employees have developed an automatic insect trap that catches insects during specified time periods only, for example at night between 9pm and 5am. The insects fall into a collector filled with liquid. Between sunrise and sunset, however, the trap is set so that diurnal insects, such as bees, can immediately return to the open air through an opening. The turntable with the trapping collectors rotates one position further each night. This means that the trap only needs to be emptied once a week as it collects samples seven nights in a row. Automatic insect traps were developed to investigate how the light colour and light intensity of LED street lights influence nocturnal insects.

Video at:  
[www.wsl.ch/object](http://www.wsl.ch/object)

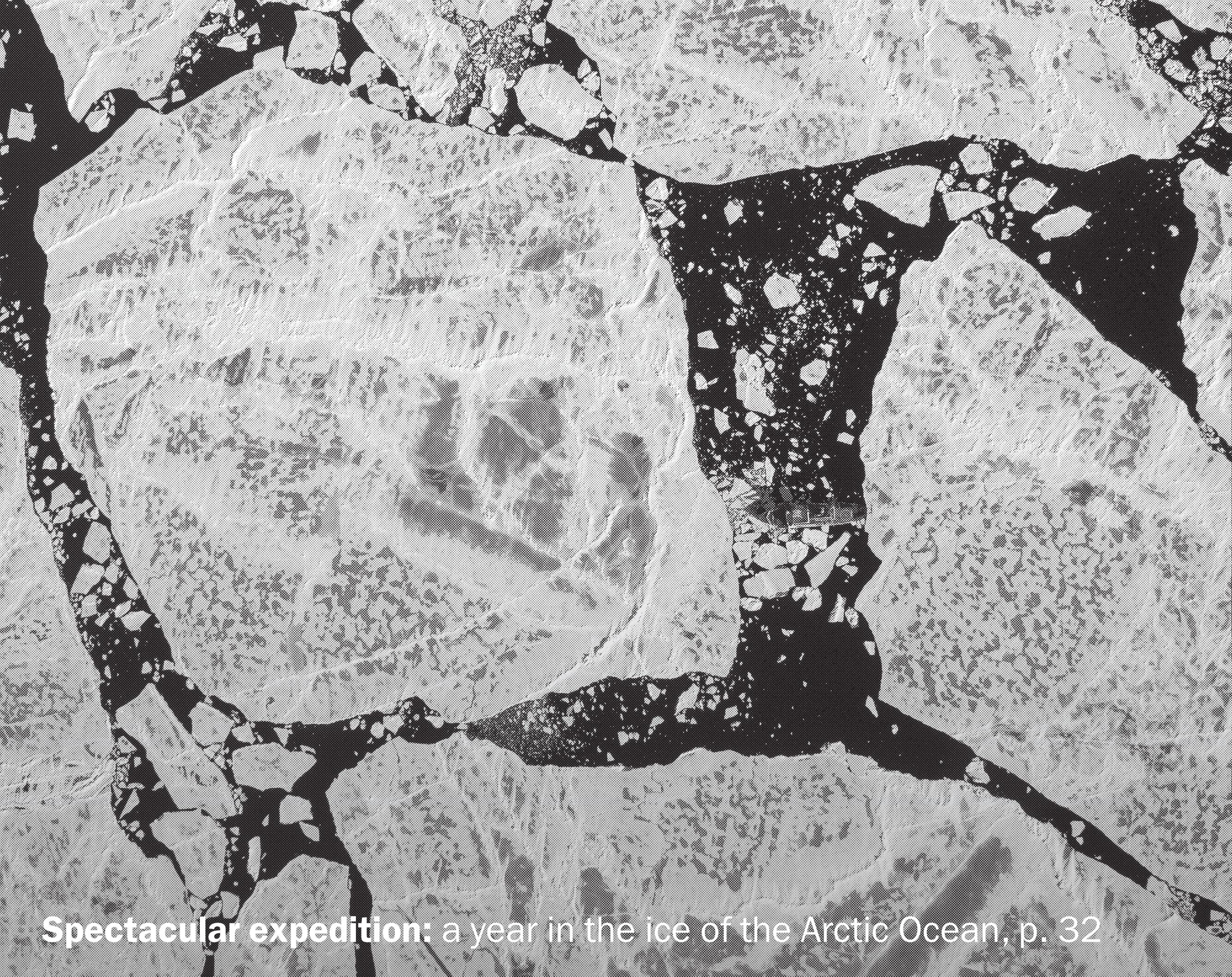






**Forest development:** test series help forestry practice, p. 21





**Spectacular expedition:** a year in the ice of the Arctic Ocean, p. 32



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## RESEARCH FOR PEOPLE AND THE ENVIRONMENT

The Swiss Federal Institute for Forest, Snow and Landscape Research WSL conducts research into changes in the terrestrial environment, as well as into the use and protection of natural spaces and cultural landscapes. It monitors the condition and development of the forests, landscapes, biodiversity, natural hazards, and snow and ice, and develops sustainable solutions for problems that are relevant to society – together with its partners from science and society. WSL plays a leading international role in these research areas, providing the basis for sustainable environmental policy in Switzerland. WSL employs more than 500 people in Birmensdorf, Cadenazzo, Lausanne, Sion and Davos (WSL Institute for Snow and Avalanche Research SLF). It is a Swiss federal research centre and part of the ETH Domain. You can find WSL's annual report online at: [www.wsl.ch/annualreport](http://www.wsl.ch/annualreport).



