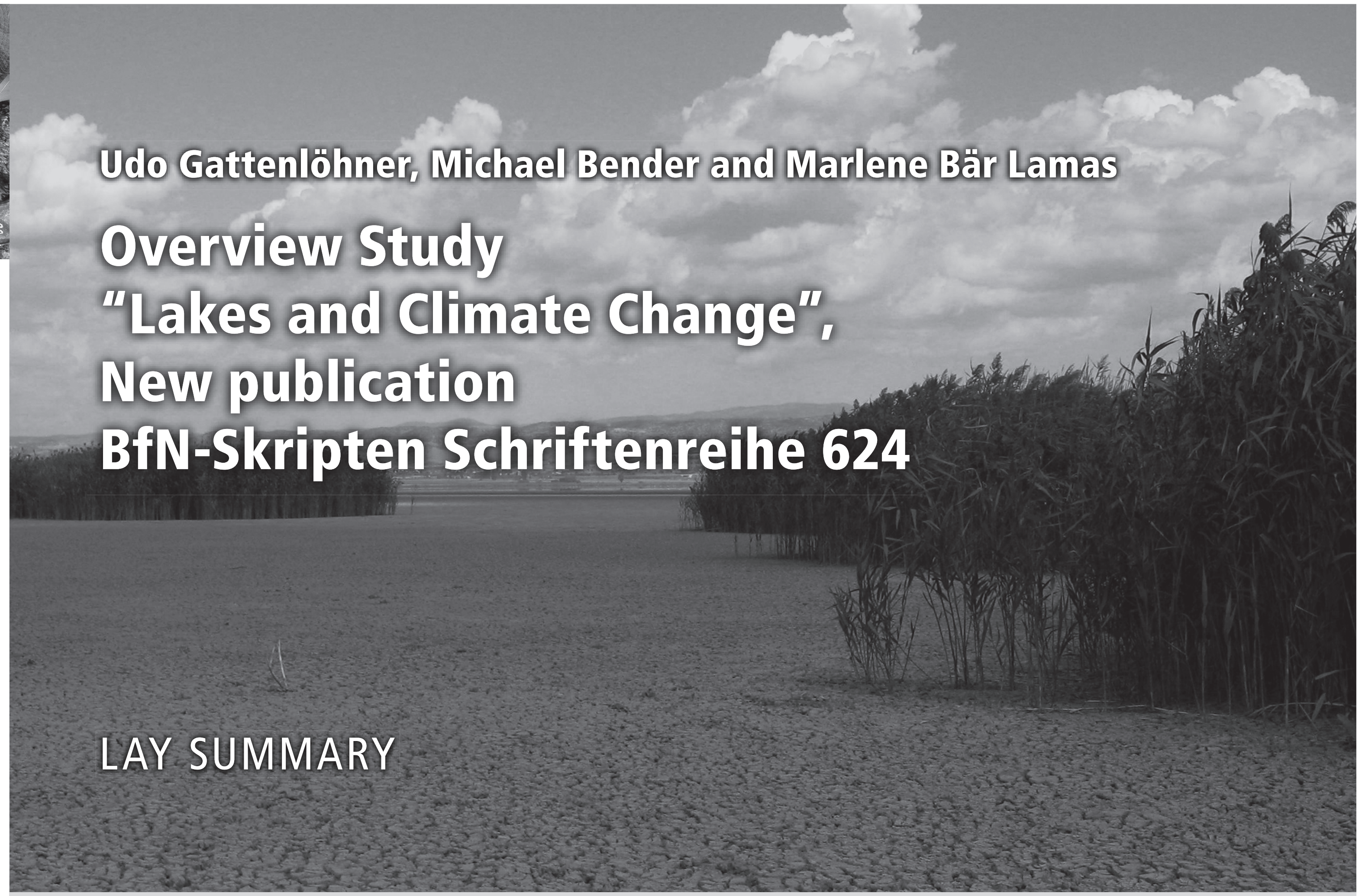


Udo Gattenlöhner, Michael Bender and Marlene Bär Lamas

Overview Study “Lakes and Climate Change”, New publication BfN-Skripten Schriftenreihe 624

LAY SUMMARY

Contributions to currently available research results on the effects of climate change – and resulting changes in temperatures, precipitation amounts and distributions - on lakes, small water bodies and wetlands in Germany, including findings from other European countries.

Global warming – and the resulting longer dry periods and more frequent heavy rainfall events – is having a noticeable effect on the water balance of lakes and wetlands in Germany and the rest of Europe. This creates additional stress factors for aquatic ecosystems and their biodiversity and increasingly reveals conflicts in water use.

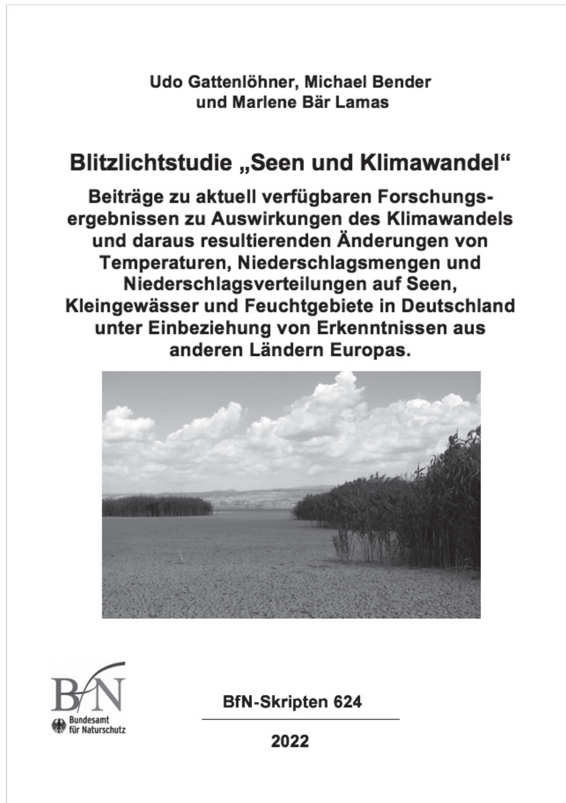
Against this background, the current “Overview study on lakes and climate change” sheds light on existing research results on lakes in Germany and Europe and draws on experiences from the international Living Lakes Network and on the findings from various “Citizen Science” projects. A full version of the study was published as a BfN-Script. The following text is a brief overview of the content and recommendations in the form of a lay summary.

The study is divided into five sections. Firstly, meteorological parameters of climate change and their impacts on biological, physical and chemical aspects – including air and water temperatures, precipitation and ice cover – are presented. In the second section, global aspects of the protection of wetlands and climate impacts on lakes are put into a European context using the example of alpine lakes in Switzerland and northern latitude lakes in Estonia.

The third part deals with the effects of climate change on lakes in Germany, especially with regard to water temperature, water quality (oxygen, pH, organic matter, nutrients, minerals, pollutants, phytoplankton), littoral zones and biodiversity (water birds and neozoa) based on contributions from the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB Berlin), the Max Planck Institute in Radolfzell and the Institute for Lake Research (ISF) in Langenargen.

The fourth chapter gives an assessment of the future developments based on the climate impacts and risk analyses for Germany, establishing a link to the current state of wetlands in order to address emerging conflicts in the field of drinking water supply, to identify possible courses of action and to make recommendations for further discussion.

The last chapter contains an extensive bibliography on the topic, including sources cited in the study.



Udo Gattenlöhner, Michael Bender
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Blitzlichtstudie „Seen und Klimawandel“

Beiträge zu aktuell verfügbaren Forschungsergebnissen zu Auswirkungen des Klimawandels und daraus resultierenden Änderungen von Temperaturen, Niederschlagsmengen und Niederschlagsverteilungen auf Seen, Kleingewässer und Feuchtgebiete in Deutschland unter Einbeziehung von Erkenntnissen aus anderen Ländern Europas.

BfN Bundesamt für Naturschutz

BfN-Skripten 624

2022

Udo Gattenlöhner, Michael Bender and Marlene Bär Lamas
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INSTITUTIONAL PUBLISHER:
German Federal Agency for Nature Conservation
(Bundesamt für Naturschutz)
Konstantinstr. 110, 53179 Bonn
website: www.bfn.de

TITLE-PAGE: Thies Geertz – Lake Volvi, located in Greece north of Thessaloniki, dried up in 2019.

This publication will be included in the Literaturdatenbank “DNL-online” (see www.dnl-online.de). BfN-Skripten are not available in bookstores. A pdf version of this issue can be downloaded under http:// www.bfn.de/skripten.html.

ISBN 978-3-89624-385-0, DOI 10.19217/skr
Bonn - Bad Godesberg 2022

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Funded by the Federal Agency for Nature Conservation (BfN) with funds of the Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection (FKZ: Z 2 53202/H/12).

Bundesministerium
für Umwelt, Naturschutz, nukleare Sicherheit
und Verbraucherschutz

Overview Study "Lakes and Climate Change"

Summary

The global warming trend and the resulting increase in longer dry periods, but also in heavy rainfall events, are having a noticeable effect on the water balance of lakes and wetlands in Germany, as well as in the rest of Europe. Both act as additional stress factors on aquatic ecosystems and their biodiversity, making conflicts in water use increasingly visible.

The present study "Lakes and Climate Change" sheds light on existing research results on lakes in Germany and Europe and includes experiences from the international Living Lakes network and findings from "Citizen Science" projects.

In their current state, many lakes are already heavily affected by human activities and thus more vulnerable to the negative impacts of climate change. Rising water temperatures, changing hydrology and increasing demands for use bring about new challenges for the protection of lake ecology. For the resistance (ability to withstand a disturbance) and resilience (ability to return to the initial state after the disturbance) of lakes to increasing extreme events, the initial conditions, including temperature level, mixing state and timing of the extreme event, are of decisive importance (cf. Adrian, Chapter 4.1). In order to protect water ecosystems and their functions, we must focus even more on the consistent avoidance of pollutant inputs, the renaturation of the banks and an extremely restrained use of their water for irrigation and cooling (cf. Lanz, Chapter 3.1).

Lakes react to the immediate effects of the weather as a result of the climate, but also indirectly to the processes in the catchment area. The summer temperatures of European lakes rose on average between 0.29 and 0.38°C per decade (cf. Dokulil, Chapter 2.1). The thermal conditions of the volumes have already changed between the 1970s and today to an extent that would be equivalent to a relocation of the lakes to significantly more southerly latitudes or to lower altitudes (cf. Adrian, Chapter 4.1).

A decrease in the ice cover of lakes can also be observed. Due to the decline in winter ice cover, some dimictic lakes have become monomictic, i.e. they are no longer completely mixed in autumn and spring (cf. Dokulil, chapter 2.1). This has negative effects on the oxygen concentrations in the deep water, even to the point of anaerobia. Anaerobic, i.e. oxygen-free conditions initiate the release of nutrients previously bound in the sediment (cf. Adrian, chapter 4.1). Global warming and the associated extreme weather events also lead to an additional increase in nutrient inputs, i.e. climate-induced eutrophication of lakes. A primary cause is the increased discharge from the catchment areas as a result of heavy rainfall and flooding (cf. Dokulil, Chapter 2.1).

Long-term measurements at lakes in Schleswig-Holstein indicate that the mean air temperature in the summer months is not of dominant importance for the development of the summer visibility depth. The temporal proximity of the precipitation event to the individually managed application of fertilisers, on the other hand, seems to be of decisive importance for algal development and for the expression of the depth of visibility in summer (Reck-Mieth, chapter 4.3).

Studies on Estonian lakes indicate that the decadal increase of blue-green algae (cyanobacteria) in shallow lakes occurs due to the interaction between local eutrophication and global warming, which bring the physical and chemical conditions in the lake closer to the cyanobacterial optimum (cf. Nõges & Nõges, chapter 3.4). Increases in chlorophyll and cyanobacteria often correlate with decreasing water levels in many lakes and reservoirs, sometimes accompanied by regime changes from clear to turbid water (cf. Bär Lamas, chapter 2.2). In some eutrophic lakes, fish kills have been observed due to oxygen deficiency and high concentrations of ammonium/ammonia (cf. Nõges & Nõges, chapter 3.4).

Climate warming and the associated increase in heat extremes lead in part to a loss of water surface. As a result, bank sediments are exposed and supplied with atmospheric oxygen. This leads to an increase in microbial degradation of organic material with the release of CO_2. This is one of the mechanisms that turn lakes and drying rivers into greenhouse gas sources for the atmosphere and thus amplify climate warming via feedback effects (cf. Adrian, Chapter 4.1).

Climate-induced fluctuations in water levels also have a significant impact on the breeding conditions for waterbirds. For example, the tufted duck has shifted its winter quarters to the north-east and has now been replaced by the coot as the most common wintering species at Lake Constance (Bauer, Werner, Chapter 4.4). Waterfowl populations also depend on the changing food supply. Surveys from dives by scuba divers have significantly improved knowledge of the distribution centres of invasive species such as quagga mussels, which are spreading in German waters in parallel with climate change (Brümmer, Schill, Chapter 4.5).

According to the Climate Impact and Risk Analysis for Germany (KWRA, cf. Chapter 5.1), the climate-induced rise in temperature will lead to increasing evaporation rates, combined with falling groundwater levels, especially in north-eastern Germany in Mecklenburg-Western Pomerania, Brandenburg and southern Saxony-Anhalt, as well as in the low mountain ranges and on the edge of the Alps. The Oldenburg-East Friesian Water Association (OOWV), which currently operates around 2,500 groundwater measuring points, has been below-average groundwater levels in the Geest areas during the last 15 to 20 years. In 2019/20, historic lows were measured here in many places. Due to the trend towards hotter and drier summers, it is to be expected that in the future there will be increased seasonal negative effects on ground-water-dependent wetlands, especially when groundwater levels are relatively low and at the same time the demand for various groundwater uses is high (cf. Buss, Chapter 5.3).

For the protection of peatlands, which must be considered as particularly endangered wetlands, paludiculture has already been successfully tested and promoted for several years as an approach to action. This approach enables use while simultaneously restoring the natural wet condition. This is of great importance because drained peatlands, which are then usually used for agriculture, emit large amounts of CO_2. Although peatlands represent only 7 % of the agricultural land used in Germany, they are responsible for 37 % of the total agricultural greenhouse gas emissions – around 43 million tonnes of CO_2 per year (including livestock). Peat decomposition or mineralisation in drained peatlands also leads to high substance discharges via ground and surface waters, which contributes to the fact that many lakes and coastal areas in Europe suffer from a high nutrient load and are highly eutrophic.

However, the carbon storage of organic soils can be restored by establishing peat-forming vegetation, e.g. through raising the groundwater level. The rewetting of peatlands will then simultaneously reduce the immense nutrient discharge of nitrogen [N] and phosphorus [P] that can be observed in drained peatlands. This must become a priority task in river basin management in north-western Europe and in the catchments of the North Sea and the Baltic Sea (cf. Bender, Wichtmann, Abel, chapter 5.2).

Recommendations

The Overview Study "Lakes and Climate Change" presents a number of research results and publications without claiming to be complete. Together with practical case studies, the Overview Study provides a basis for initial conclusions and recommendations, which are summarised below in the form of central theses for further discussion.

In addition to already discernible changes in weather, wind and especially temperatures, which can be partially extrapolated for the future, ecological conditions (e.g. expansion of neobiota) and additional demands for use that are expected in the future or are already emerging are changing at the same time. These are partly outlined in the study, e.g. cooling water, but also include other aspects, such as the development of aquaculture, which are not specifically described here.

Many lakes and wetlands are already at the limits of their hydrological and ecosystem resilience. It must be ensured that current and past successes in the management of water bodies are not lost due to negative developments and new demands. Therefore, existing uses of lakes and wetlands as well as additional demands must be critically examined and prioritised against the background of expected climate developments, with the aim of reducing the overall pressure on ecosystems and ensuring an ecological balance.

In all German river basins, nutrient pollution is one of the important water management issues according to Article 14.1.b of the Water Framework Directive (WFD). Eutrophication is considered one of the main causes for the failure to achieve the good ecological status of surface waters are formulated in the WFD, and nitrate pollution is considered the main factor for the failure to achieve the good chemical status of groundwater. Current climate research on lakes and their catchment areas points to factors that will lead to additional nutrient inputs and thus to increased algal blooms in water bodies. Targets and framework conditions to reduce nutrient inputs should take into account both the higher probability of additional inputs from the catchment area, for example due to heavy rainfall events, and other additional pressures.

In addition to the data collected by responsible agencies at federal and state level, other institutions, such as water suppliers or "Citizen Science" projects, have comprehensive data, some of which has been available for many years. These sources should be consulted on a much larger scale for the inventory and the derivation of necessary measures. Regarding nutrient pollution, this also applies especially to all data collected in connection with agricultural management.

When water suppliers (such as the OOWV) report the lowest groundwater levels ever measured, this can be seen as a further indication of a large-scale decline in groundwater-dependent wetlands and small water bodies as well as lake areas. How large the extent of this development that has occurred so far and its overall effect on the decline of aquatic biodiversity already is, does not seem to be fully understood at present. In addition to the need for research that is indicated here, there are several calls for action, such as near-natural water retention, which are becoming increasingly important in terms of both biodiversity conservation and climate protection. Especially effective in terms of reducing CO_2 and methane emissions are the raising of water levels and the rewetting of peatlands, 98 % of which are currently artificially drained. A major focus of action should be set on the former peatlands drained for agricultural use, which, along with animal farming, are among the hotspots of agricultural climate gas emissions. Here it is necessary to expand peatland protection for the purposes of nature conservation, climate protection and climate adaptation, and to significantly expand measures for adapted use under humid conditions (called paludiculture). The drainage of wet sites for conventional cultivation must become a custom of the past.

In their current state, many lakes are heavily polluted by human activities so that they cannot withstand climate change unscathed. In times of warmer and drier summers, they need even better protection. This means, above all, the consistent avoidance of pollutant inputs, the renaturation of the shores and an extremely restrained use of the water. Due attention should be given to strategic environmental assessments of planned shoreline constructions, taking into account the limited carrying capacity of lakes. More extensive buffer zones and unused riparian strips should be created, and near-natural shallow water zones should be restored more extensively. Guidance documents on the design of riparian strips have been produced by various federal states of Germany (see e.g. LUBW and WBWF, Riparian strips in Baden-Württemberg, 2015). To improve funding opportunities, a nationwide funding programme for the renaturation of lakes and wetlands is required.

If climate change and variability are not proactively addressed, the chances of success of long-term protection and conservation plans are significantly reduced. Measures to control invasive species are also essential in this regard, as changing climate conditions increase the risk of invasive species spreading.

Climate adaptation measures in northern temperate zones include consistently sustainable agriculture, improved nutrient and soil management with reduced nutrient losses to surface waters, reduced point source pollution, restoration of degraded wetlands and riparian zones, and restoration of channelled rivers. In drier southern Europe, human water use needs to be restricted, especially in irrigated agriculture. The success of these measures will largely depend on the involvement of local communities in the adaptation process.