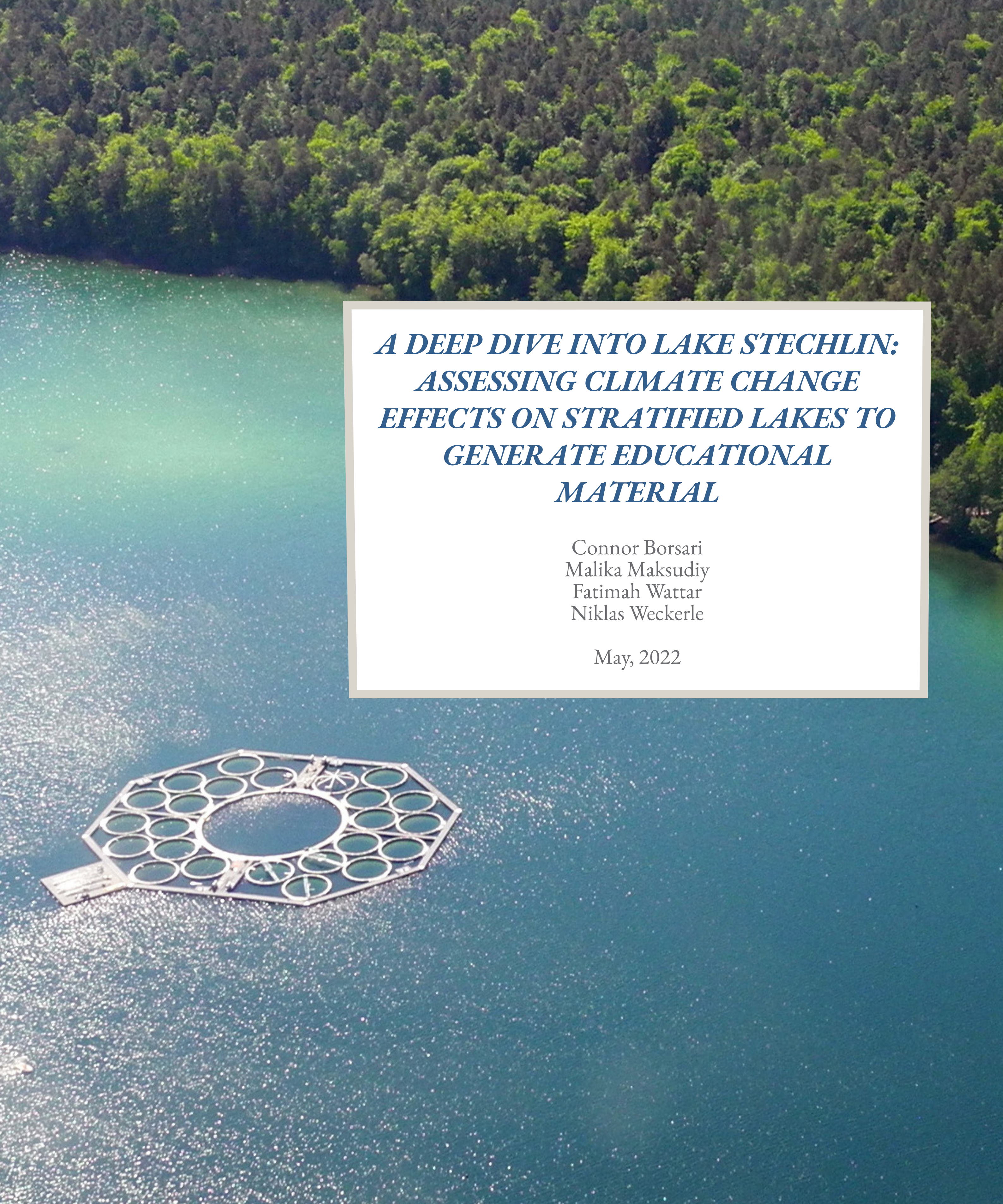

A DEEP DIVE INTO LAKE STECHLIN: ASSESSING CLIMATE CHANGE EFFECTS ON STRATIFIED LAKES TO GENERATE EDUCATIONAL MATERIAL

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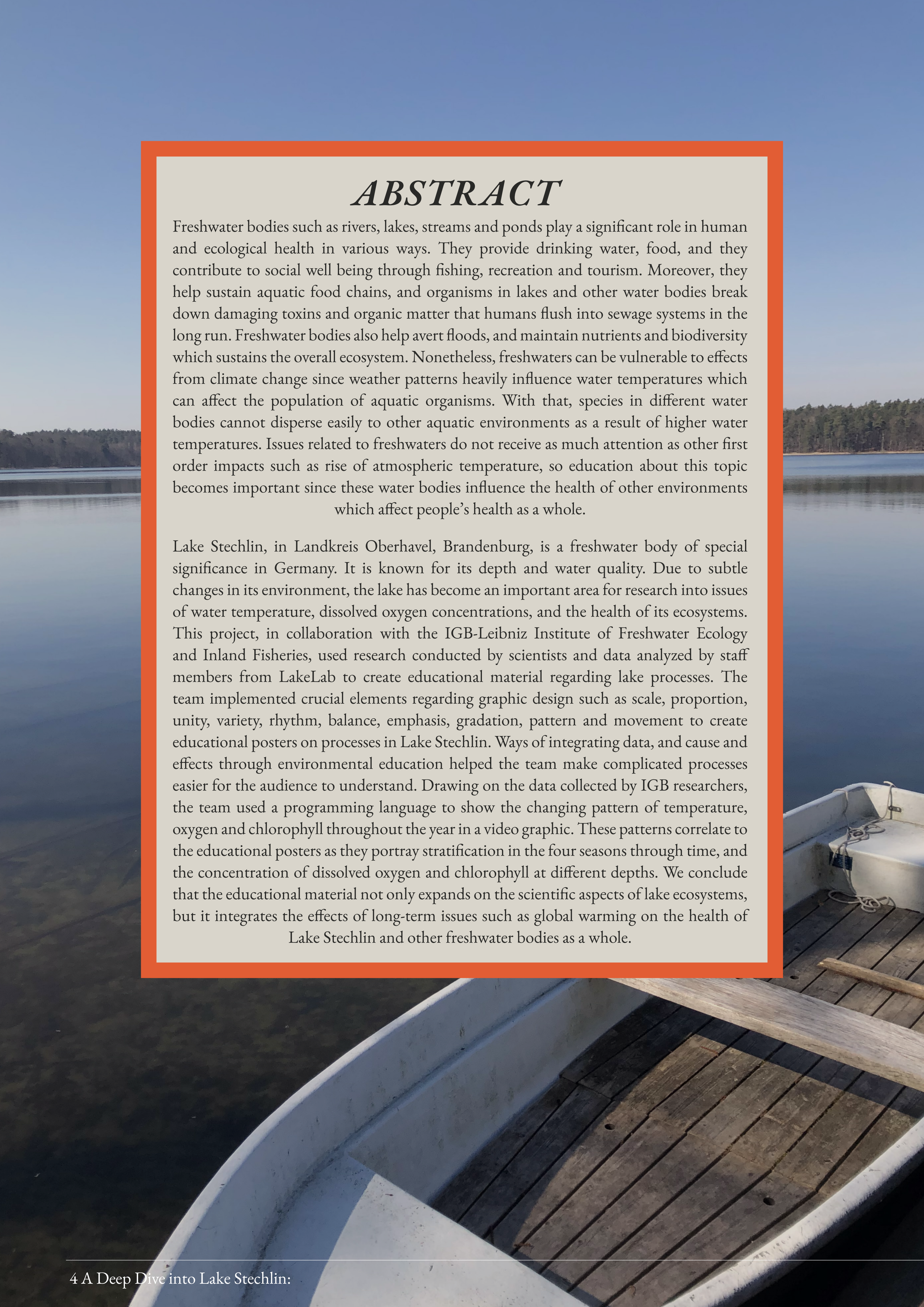


ABSTRACT

Freshwater bodies such as rivers, lakes, streams and ponds play a significant role in human and ecological health in various ways. They provide drinking water, food, and they contribute to social well being through fishing, recreation and tourism. Moreover, they help sustain aquatic food chains, and organisms in lakes and other water bodies break down damaging toxins and organic matter that humans flush into sewage systems in the long run. Freshwater bodies also help avert floods, and maintain nutrients and biodiversity which sustains the overall ecosystem. Nonetheless, freshwaters can be vulnerable to effects from climate change since weather patterns heavily influence water temperatures which can affect the population of aquatic organisms. With that, species in different water bodies cannot disperse easily to other aquatic environments as a result of higher water temperatures. Issues related to freshwaters do not receive as much attention as other first order impacts such as rise of atmospheric temperature, so education about this topic becomes important since these water bodies influence the health of other environments which affect people's health as a whole.

Lake Stechlin, in Landkreis Oberhavel, Brandenburg, is a freshwater body of special significance in Germany. It is known for its depth and water quality. Due to subtle changes in its environment, the lake has become an important area for research into issues of water temperature, dissolved oxygen concentrations, and the health of its ecosystems. This project, in collaboration with the IGB-Leibniz Institute of Freshwater Ecology and Inland Fisheries, used research conducted by scientists and data analyzed by staff members from LakeLab to create educational material regarding lake processes. The team implemented crucial elements regarding graphic design such as scale, proportion, unity, variety, rhythm, balance, emphasis, gradation, pattern and movement to create educational posters on processes in Lake Stechlin. Ways of integrating data, and cause and effects through environmental education helped the team make complicated processes easier for the audience to understand. Drawing on the data collected by IGB researchers, the team used a programming language to show the changing pattern of temperature, oxygen and chlorophyll throughout the year in a video graphic. These patterns correlate to the educational posters as they portray stratification in the four seasons through time, and the concentration of dissolved oxygen and chlorophyll at different depths. We conclude that the educational material not only expands on the scientific aspects of lake ecosystems, but it integrates the effects of long-term issues such as global warming on the health of Lake Stechlin and other freshwater bodies as a whole.

IMPORTANCE

Freshwater bodies are an essential resource that provide an array of environmental, economic, and cultural benefits, however, these ecosystems are vulnerable to changes and therefore need protecting. Lakes are home to an array of organisms, which rely on the health of these freshwater bodies to survive. Over 10% of all recorded species as well as about 30% of all vertebrates live in freshwater ecosystems [1]. Additionally, lakes attract tourists, which benefit the local economy. Other benefits of freshwater ecosystems include but are not limited to, water supply, crop irrigation, and water quality control [2]. In numerous lakes, excess phosphorus and nitrogen can cause algae blooms, and some types of algae blooms can produce toxins that contaminate drinking water systems, which can be harmful to aquatic life and humans over the years. Therefore, action is necessary to protect these ecosystems.

Relevance

Freshwater bodies play an important part in every society's culture and Germany is no exception. Germany is a country rich in water, as it makes up 2.2% of Germany's surface area. Some of that surface area is taken up by Germany's eleven large rivers. Moreover, 0.85% of the surface area comprises natural lakes [3]. These freshwater bodies are very important to Germany as approximately 56% of this surface water is used as cooling water, 18% is used in mining and industry, 1% in agriculture and forestry, and about 13% for public water supply [3]. Secondly, many citizens benefit from lakes because of the activities they offer, such as swimming and kayaking [4]. These activities can reduce stress and anxiety in people leading to a higher morale overall. Additionally, in many religions water is viewed as life, purity, renewal and reconciliation, making them culturally important to those religious groups. Therefore, given the country's relationship with bodies of water, it is of the utmost importance that oligotrophic landscapes are protected. Even slight disruptions in the German water system caused by excessive nutrient levels and algae blooms could negatively impact German communities.

Current Issues

Increase in algae blooms is correlated with increased surface temperatures in lakes due to changes in temperature and overall weather pattern: in short, climate change is wreaking havoc on lakes in Germany. Its effects could have irreversible impacts on freshwater ecosystems, leading to decreased amounts of drinking water for communities. Warmer temperatures prolong thermal stratification, and in this process, warmer surface waters can resist the wind's ability to mix the water. The layers prohibit the flow of oxygen and nutrients in water, and in return, the oxygen gets used up in the bottom of the lake, increasing the amount of algae in water bodies. As dissolved oxygen decreases it is more difficult for fish and aquatic life to survive, and the blooms release toxins that make it difficult to remove cyanobacteria cells in water treatment. This leads to adverse health effects for fish such as stomach and liver issues.

The Disconnect

Informing the public on the effects of climate change and pollution on stratified lakes is needed in order to combat the effects climate change and pollution have on stratified lakes. Research indicates that people who are informed on the status of the climate are willing to act. Germans who are considered alarmed on climate change issues are reportedly willing to give up certain living conveniences to combat climate change [6]. However, there are still many people who are ill informed about the importance of freshwater lakes, such as Lake Stechlin and the impacts climate change is having on them [7], showing an apparent need for improvement in the environmental education used for bridging the gap between the information and the public.

LAKE STECHLIN

Lake Stechlin, in particular, located north of Berlin in Brandenburg, is one of the most important oligotrophic landscapes of Central Europe. Oligotrophic landscapes are aquatic habitats with low levels of nutrients and vegetation. The lack of new nutrient sources may be a driving evolutionary force leading to greater specialization and diversity [5]. Lake Stechlin is being monitored to ensure the health of this landscape, as dramatic changes in attributes such as water temperature, could be detrimental to sensitive species [5]. Another oligotrophic attribute found in Lake Stechlin is its extremely clear water. It has made Lake Stechlin a popular tourist attraction for decades. Indeed, the lake is so well known that it became the centerpiece and title of Theodor Fontane's final novel in 1898. This body of water's scientific and cultural significance places it at the forefront of German preservation goals. In order to achieve this goal, it is essential to increase public education on the subject.

The Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB) is working to identify the negative effects climate change has on lakes. The IGB has constructed a lake laboratory for identifying the effects that climate change is having on specific lake processes. Although its research is extensive, the IGB has been struggling with communicating research to the public. It was our team's goal to provide educational material to the IGB, which they can use to educate the public about processes at Lake Stechlin during open houses. To accomplish this goal, we identified three objectives:

Design posters regarding lake stratification in English and German

Use a programming language to generate lake parameter plots that display the state of lake processes throughout a whole calendar year

Evaluate the educational material

FRESHWATER ECOSYSTEMS ARE VITAL TO THE ENVIRONMENT

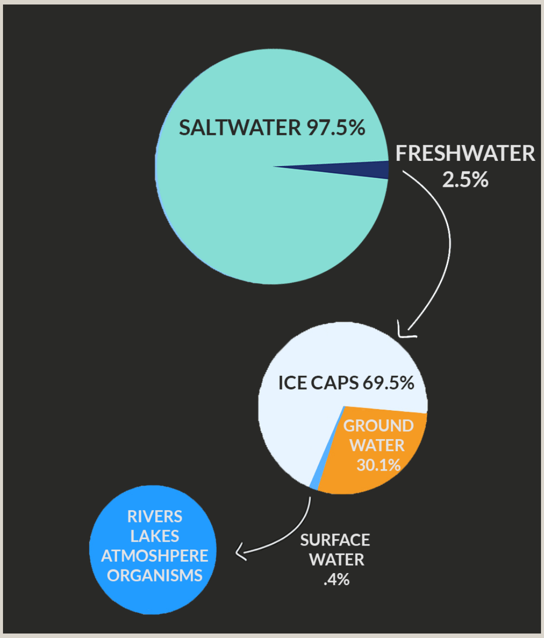


Figure 1: Pie Chart of Composition of Fresh Waters

Freshwater ecosystems play a crucial ecological, economic, and cultural role, yet they are one of the most threatened in the world, with global declines in their surface area by 64% from 1997 to 2011 [1]. Freshwaters consist of lakes, rivers, ponds, streams, wetlands, floodplains, and groundwater. Altogether, they comprise only 3% of the water on Earth and constitute less than one-tenth of Earth's land surface area (Figure 1). However, even with such small numbers, they still support over 10% of all recorded species including about 30% of all vertebrates [1].

Even though freshwater ecosystems are scarce, they provide many services. Among these services are recreation and tourism, water supply, water quality control, and erosion prevention [8]. They also provide provisional services such as supplying fertile soils for agriculture, habitat provision, reeds for construction, drinking water, and food such as fish, crustaceans, and mollusks. Freshwater ecosystems also are important in regulation of the environment through groundwater recharge, flood regulation, microclimate regulation, carbon sequestration, and water quality control. Some of the economic benefits freshwater ecosystems provide are fisheries, fuelwood, building material, medicinal products, honey, and foliage. Agriculture, forestry, and fishing are the biggest economic sectors that utilize fresh water. 58.3% of water use was in agriculture in Europe in 2017 [9], demonstrating the importance of freshwater for irrigation. Besides the numerous services they provide to humans, freshwater ecosystems provide critical habitats for a large number of aquatic plants, fish, reptiles, birds, and mammals. They also host many migratory and threatened species of birds, reptiles, fish, and mammals [10].

"WATER IS THE ESSENCE OF LIFE"

JEAN-MICHEL COUSTEAU

JEAN-MITCHEL COUSTEU IS A FRENCH ENVIRONMENTALIST THAT DEVOTED HIMSELF TO EDUCATING THE PUBLIC ON THE IMPORTANCE OF WATER ON OUR PLANET

Aside from the huge impact that freshwater ecosystems have on the economy and the environment, they carry an important social significance. Given the large-scale urbanization that has impacted most of the modern world, natural resources such as freshwater ecosystems have provided and continue to provide an important escape from busy cities. In particular, freshwater ecosystems such as lakes are often landmarks for surrounding communities. These landmark bodies of water have been connected to a decrease in anxiety/mood disorder hospitalizations [11]. Therefore, healthy natural landmarks can boost the overall morale in surrounding communities. Communities with well maintained freshwater ecosystems also promote physical activity through swimming, hiking, and fishing, all of which help to keep community members healthy. Researchers at the University of New Taipei City, for example, discovered that people report a decrease in their depression after swimming [4]. When these natural resources disappear, communities can lose these healthy and productive benefits. Researchers estimated that the average predicted anxiety/mood disorder hospitalization would be around 1.2 for around 40,000 people. This value would drop to only 0.86 if there are inland lakes in the area [11].

"Water is the essence of life", as Jean-Michel Cousteau once said. Throughout human history water has consistently taken a significant role [12]. In many religions' sacred texts, for example, significant events happen around water, such as Jesus walking on water to prove his faith in God and Moses parting the Red Sea to escape the Egyptian plagues [Bible]. In rituals of various religions, water is used for bathing, washing, drinking, or as a sacrifice [13]. Kumbh Mela, for example, is a Hindu festival centered around four sacred rivers in India, which drew in more than 200 million people in 2019 [14]. At the event many people bathed in the sacred rivers, which they considered the essence of purity, auspiciousness, and immortality. Water is viewed as life, purity, renewal and reconciliation. These rituals are vital to religious groups to feel culturally fulfilled, the health of the freshwater ecosystems is therefore vital. It is essential that natural processes are understood and natural resources are carefully managed.

ENVIRONMENTAL EDUCATION

Outreach

The management of these natural resources starts with the environmental education of young people. Many ecological problems such as increasing pollution, the accumulation of huge amounts of waste, the depletion of natural resources, and climate change need to be remedied and can only happen if there is a sufficient level of environmental knowledge and eco-consciousness, the formation of which begins in early childhood [15]. An Australian survey that assessed levels of environmental concern and behavior found that education on the environment was associated with higher levels of ecocentric concerns and ecological behavior16. Moreover, an experimental study conducted by Duerden and Witt (2010) revealed that indirect (classroom) experience was a significant, positive predictor of environmental behavior among middle and high school students. Additionally, they found that direct experience (nature immersion) influences attitudes and future behaviors [16]. Therefore, education starting from a young age is vital to influencing future behavior.

To address the environmental crisis, many organizations, such as the North American Association for Environmental Education (NAAEE), have sought to engage the public on the significance of global environmental changes, referred to as sustainability challenges [17]. Education on their significance is important because it results in higher public engagement, which can hinder the effects of climate change. By creating an informed citizenry, increasing the chances of research being adopted, increasing public trust, and fostering global communication, effects of climate change can be hindered [18].

Goals

Effects

Environmental education (EE) is an important way to create an informed citizenry. EE emerged in the 1960s out of a need to respond to an emergent environmental crisis [17]. Currently, EE focuses on engagement through participatory action, by developing the ecological and environmental literacy required to understand environmental issues and resolve them [17]. EE “helps individuals, communities, and organizations learn more about the environment and develop skills and understanding about how to address global challenges” [19]. It has the power to transform lives and society. As the NAAEE reported, “EE is built on the principles of sustainability, focusing on how people and nature can exist in productive harmony.” [19] EE is a powerful method of engaging and informing the public on sustainability challenges, helping to benefit the general population.

ADDRESSING GAPS IN OUTREACH

An area of environmental education lacking sufficient discussion is the effects of climate change and pollution on freshwater ecosystems. Rivers, lakes, and wetlands are under intense pressure from multiple use, pollution and habitat degradation [20]. These fresh waters are particularly vulnerable to climate change because many species within these habitats have limited abilities to disperse as the environment changes with several aquatic species disappearing from entire ecosystems [20]. Lake Stechlin, a freshwater ecosystem located in Germany, for example, has a native fish species, the Coregonus fontanae, that is now endangered as it is exclusive to Lake Stechlin. Fish species such as the Coregonus fontanae (shown below in figure 2) would benefit from environmental education as it has proven to result in better water management behavior [21]. Implementing environmental education has been challenging, however, due to lack of adequate literature and specially trained people [22].

Developing new forms of environmental education on climate change can help mitigate the negative effects of climate change. The UN Framework Convention on Climate Change (UNFCCC) Article 6 on education, training, and public awareness states that "countries shall develop and implement educational and public awareness programmes on climate change and its effects" [23]. The Paris Climate Agreement Article 12 reiterates the importance of environmental education in enhancing climate actions [23]. In fact, a coreelement of the Paris Agreement Article 12 reiterates the importance of environmental education in enhancing climate actions [23]. In fact, a core element of the Paris Agreement is the NDC, the Nationally Determined Contributions, a climate action plan to cut emissions and adapt to climate impacts.

Despite this, many countries are not including educational issues in national priorities for climate mitigation and adaptation actions through the NDC. As YOUNGO notes, there is generally a lack of acknowledgement and integration of education and youth in the climate priority setting of countries [23]. Out of the 196 Parties to the UNFCCC, only 32% mention education as a means to combat climate change and are often limited to school curriculum [24].

Figure 2: Coregonus fontanae a fish species only found in Lake Stechhlin

EFFECTS OF CLIMATE CHANGE ON LAKE STRATIFICATION

Lakes are a particular freshwater system vulnerable to changes in climate. Many temperate lakes are becoming anoxic, a condition where lakes are losing dissolved oxygen, which is a key indicator of lake health [24]. The concentration of dissolved oxygen in aquatic systems helps to regulate biodiversity, nutrient biogeochemistry, greenhouse gas emissions, and the quality of drinking water [25]. Anoxia can also harm cold-water fish species and contribute to algae blooms that do even more damage to the lake. Researchers compiled data on dissolved oxygen concentrations in more than 300 lakes in temperate zones and found that the oxygen decline in freshwater was happening at a rate up to 9.3 times greater than in oceans, and that climate change and a lack of water clarity had changed the physical and chemical makeup of those lakes too [24]. In their analysis, the team found that due to climate change, surface temperatures have been rising while the deeper waters of the lakes remain cool. In that process, the lakes increasingly lose their oxygen due to a longer stratification period.

Lake stratification is a vital process for the organisms as it distributes oxygen throughout the lake. Stratification is a natural process in which a lake forms distinct thermal layers during warmer weather. During the turnover season, the layers mix where a lake's deep cold waters (hypolimnion) mix with the warmer waters at the surface of the lake (epilimnion) along the middle layer called the metalimnion [26]. This process is heavily dependent on seasons as the warm surface waters are generated during the summer months of the year. This mixing of the lake's varying temperature layers is important as it is predominantly a way of dispersing nutrients and matter around the lake. The warmer layers often contain the bulk of the lake's living organisms, where the colder deeper parts of the lake contain the decaying plant and organism matter which is recycled into useful nutrients.

One of the most essential chemical compounds that organisms rely on for survival in stratified lakes is dissolved oxygen. Dissolved oxygen is generated from submerged plants. It accumulates in the warmer upper layers of the lake and is used by fish and other living organisms. It is essential that a portion of this dissolved oxygen is mixed back in with the colder deeper parts of the lake as the microorganisms responsible for the decomposition of organic matter require it to function. This decomposition process is what generates the essential nutrients that the other organisms need for survival. A simple diagram of lake stratification with each season is visible in the figure below (Figure 3).

Events associated with climate change have a major effect on stratification. Heat waves increase overall biological productivity in stratified lakes. One study showed that after a recent heat wave, "average chlorophyll a concentrations and cyanobacteria biomass peaks were up to 39% and 58% higher" [27]. Furthermore, increased cyanobacteria on the bed of lakes shield sunlight, harming plant life. Similarly, increased hurricanes result in thermocline deepening. The thermocline layer is virtually impenetrable by any organisms and creates a boundary between the cold deep water and warm, well mixed upper water. Any fluctuation in the size and depth of the thermocline can be detrimental to the processes that occur in the two neighboring layers of water.

LAKE TURNOVER

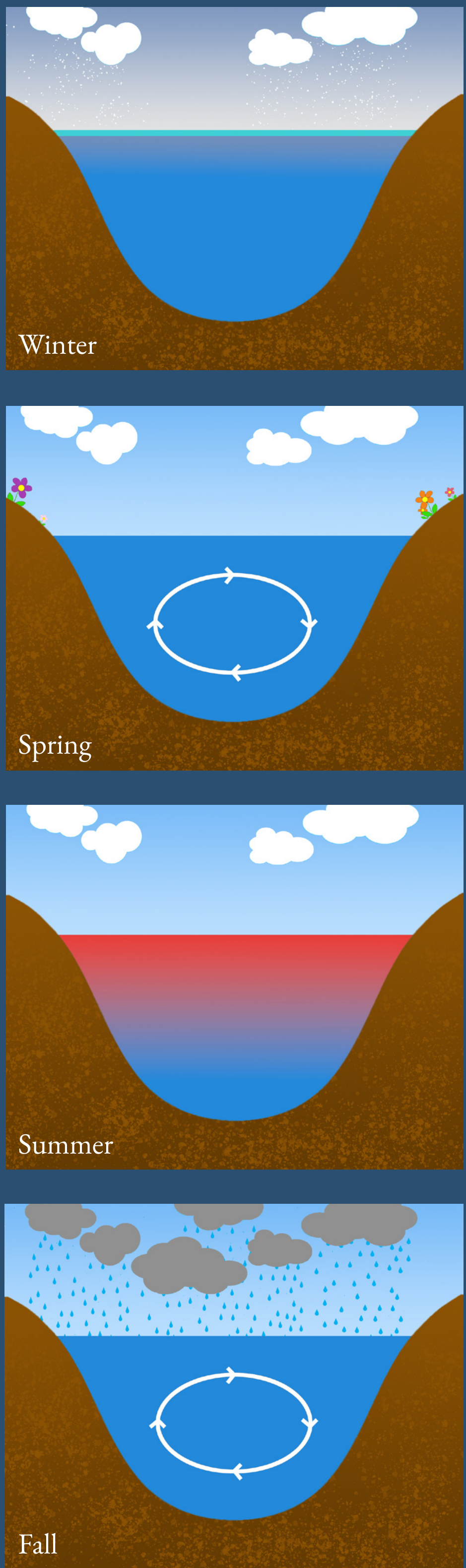


Figure 3: Simple Stratification Cyle Diagram

Rising temperatures have shortened the overall length of seasons, affecting the stratification period. Globally, winters have become warmer as the average surface temperature has increased by approximately 0.6°C over the past century [27]. Considering that the major mixing cycles occur at either end of the winter season, the summer mixing process is beginning earlier in the year and the stratification period is lasting longer, where the layers are separate for a longer period of time. Therefore, the nutrients are not being dispersed in time.

There are a number of additional sources which are raising the temperature of lakes globally, one of which is pollution. Thermal pollution from nuclear power plants has played a major role in increased lake temperatures. Nuclear power plants have become one of the greatest local sources of thermal pollution as their cooling process requires large amounts of water and produces extremely high levels of energy [28]. As the temperature of stratified lakes increases, “the warmer water accelerates the metabolism of the organisms in the lake resulting in oxygen depletion in the deep water” [29]. Lake turnover is responsible for resupplying oxygen to this layer. The issue arises as increased metabolism of the organisms results in increased waste which needs to be broken down by lakebed microorganisms. This decomposition requires oxygen which is already in short supply. Increased water temperature affects stratified lakes’ ability to keep up with the demand of dissolved oxygen in both the upper and lower sections of the water making them less hospitable to their respective organisms. Many of the organisms found in stratified lakes generate a large amount of revenue for local populations and the loss of any of these resources could be economically unfavorable.

LAKE STECHLIN

Lake Stechlin has been studied by researchers due to its long history and oligotrophic attributes. The history around the formation of this lake dates back to roughly 12,000 years ago. At this point, large masses of ice that are thought to have been up to 1,000 meters thick could be found throughout the North German plain. These masses of ice were responsible for both the carving of the lake body and the surrounding land formations that can be seen today. After years of foresting and construction, the biological diversity of the lake was being adversely affected. For this reason, the lake was placed under protection in the 1930s [7]. Today Lake Stechlin is part of the European Natura-2000 ecological protection network, and it is home to a number of protected species, which includes the Osprey, white-tailed eagle, kite, cormorant, kingfisher, common tern, many species of dragonfly, beaver, stag beetle and many other species [30]. The clear water at Lake Stechlin has a number of environmental and social benefits. The clear water can be accredited to the lack of algae which require nutrients that are scarce in the lake [7]. These attributes allow the lake to be categorized as an oligotrophic landscape. The clear water allows for plants on the lake surface to grow more easily given the increased sun exposure. Lake Stechlin is actually the clearest lake in all of Germany, which is a main selling point for tourism. The income generated by this tourism now plays an essential role in the economy of the surrounding towns [31], which in turn helps support The IGB's research. Tourism aside, this lake has existed since long before any communities were developed around it and has earned its spot as an important piece of natural German history.

CHANGING PROCESSES

AT LAKE STECHLIN

Nuclear Power Plants

Research on Lake Stechlin highlights that several pattern changes in lake processes were caused by long-term effects of a nearby nuclear power plant (NPP) and global weather changes. In the scope of Lake Stechlin, NPPs play a large role in thermal stress given the lake's geographic positioning with respect to the now decommissioned plant. According to the IGB, "from 1966 to 1990, the Rheinsberg nuclear power plant was operated near Lake Stechlin. Heated by about 10 degrees Celsius, this cooling water ultimately flowed into Lake Stechlin." In nuclear power, process water is reused in the power generation process, but the cooling water is discharged back into a lake or river at a temperature typically around 30-40°C [29]. Normally, "the mean monthly temperatures in Lake Stechlin vary between -0.8 °C in January and 17.3 °C in July," [32] but due to the cooling water from the nearby power plant, there was an average increase in water temperatures by 1–2 °C. This rapid temperature increase, which occurred in a 27-year window, had major effects on Lake Stechlin. However, the power plant was decommissioned over 30 years ago, so currently the main cause of increased water temperature is climate change. Overall long-term effects of the NPP revolve around increased duration of summer stratification, which is related to increased amounts of algae blooms, which lowered the transparency of water at the surface.

Weather Patterns

General weather patterns have contributed to recent changes in Lake Stechlin. Warm temperatures during the winter mixing period of stratification increased water temperatures by about 0.5–1.0 °C between 1958–1966 and 1991–2009 [32]. The IGB has also concluded that "increased temperatures, decreased rain, altered wind conditions and other extreme events resulted in changes in thermal stratification, nutrient availability, material turnover rates, diversity and composition of organisms and concentration of oxygen." Researchers at the IGB stated that, "Over the last 50 years, the surface water has warmed by more than 1.5C." Increase in temperature is also linked to oxygen depletion in the hypolimnion due to increased metabolism in organisms, which will ultimately affect other fish in the freshwater. These changes can have significant impacts on the lake's biodiversity.

Phytoplankton Populations

Another important aspect of changes in stratification in Lake Stechlin is the increase in phytoplankton population. Phytoplankton are microscopic organisms such as protists or single-celled plants that consume carbon dioxide, and release oxygen. According to one study, increases in cyanobacteria, a type of phytoplankton, can decrease the health of other species through increased respiration rates or egg abortion [33]. Not only are other important phytoplankton species affected but with more cyanobacteria, there will be more toxins that are harmful to people's health and can destroy fish and animal populations.

METHODS

The team's goal was to collaborate with the IGB (Leibniz Institute of Freshwater Ecology and Inland Fisheries) to create educational material on the importance of freshwater ecosystems. The intent was to educate high school students and visitors during open house events on the changes stratified lakes have been experiencing in recent years due to external factors such as climate change. To do this, the team worked through the following three objectives. Our principal methods included interviews with stakeholders and technicians and focus groups with high school students.

OBJECTIVE 1

Design posters regarding lake stratification in English and German

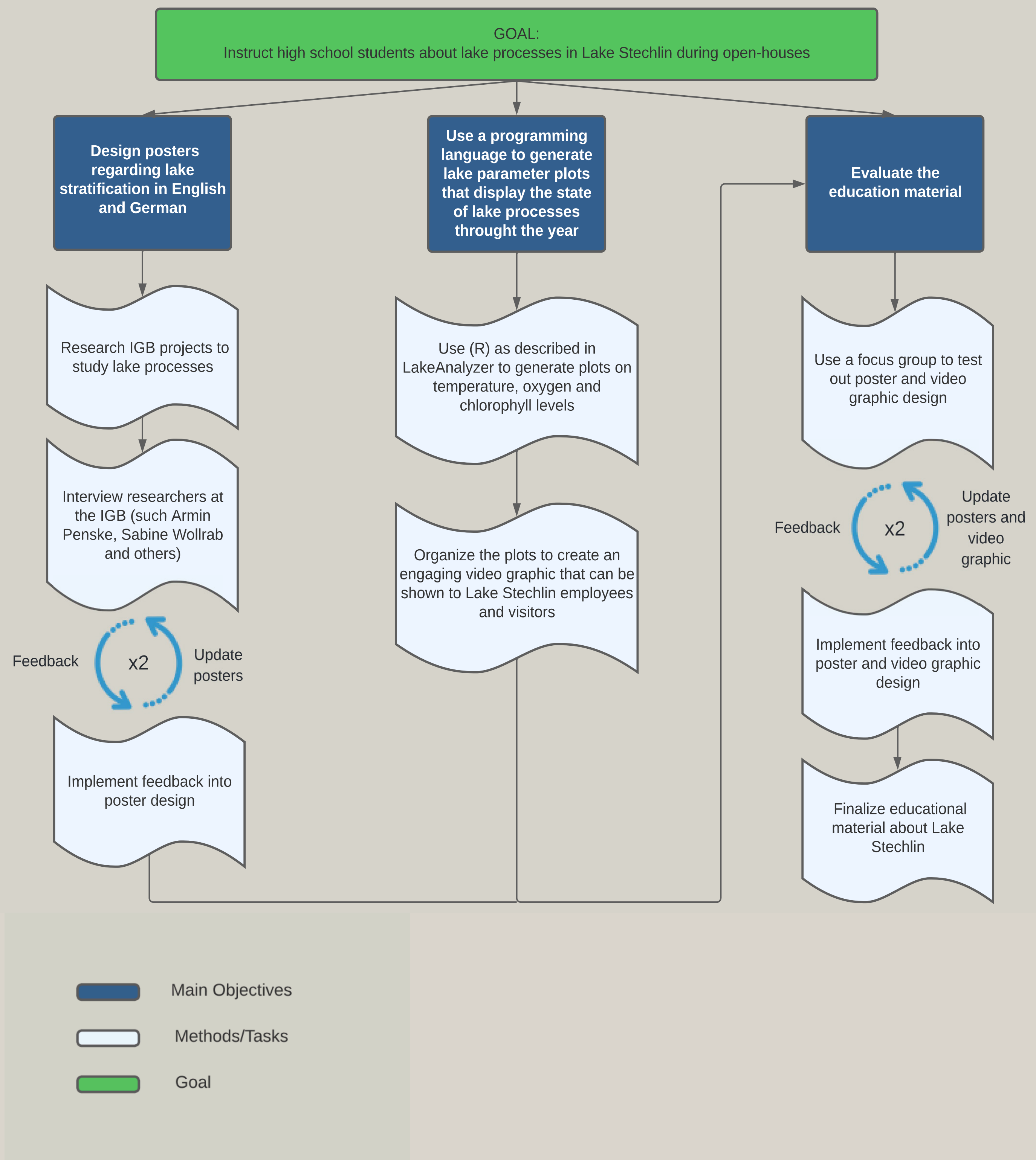
OBJECTIVE 2

Use a programming language to generate lake parameter plots that display the state of lake processes throughout a whole calendar year

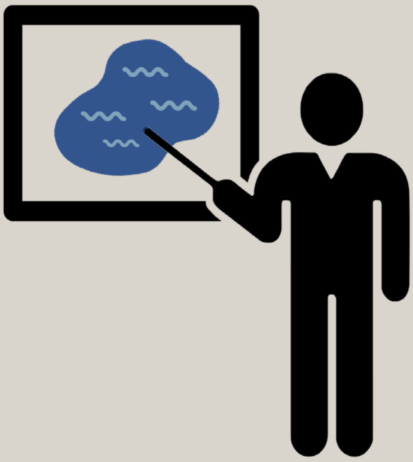
OBJECTIVE 3

Evaluate the educational material

PROJECT METHODOLOGY DIAGRAM



Case Introduction



The project was based on information from Lake Stechlin in Landkreis Oberhavel, Brandenburg, Germany, which is around 80 km north of Berlin. It is a 228 ft deep clear water lake, and its basin was formed during the last continental glaciation about 12,000 years ago (See Appendix H). Given the lake's clear water and high biodiversity, as well as its history involving nuclear power plants, Lake Stechlin has become an ideal location for IGB research. Our sponsor, the IGB (Leibniz Institute of Freshwater Ecology and Inland Fisheries), founded in 1992, is one of Germany's largest institutions that focuses on research on freshwaters (See Appendix A). Its goal is to study global environmental changes and to develop ways to sustain water processes. One of its largest experimental setups is called "LakeLab" in Lake Stechlin, which is made up of a central reservoir and 24 lake-water basins. In each of the enclosures, there are lowerable probes (Figure 8) that continuously gather data at different depths. The data is transmitted to a computer and stored in a database, which produces records of different water properties.

Figure 4: Water Probes used at LakeLab to collect Data

OBJECTIVE I

DESIGN POSTERS REGARDING LAKE STRATIFICATION IN ENGLISH AND GERMAN

We designed posters to teach students visiting Lake Stechlin about the importance of stratified lakes. Understanding the stratification process is crucial because this knowledge is necessary for preservation. To design posters regarding lake stratification, we needed to know the process of lake stratification over different seasons, the effects of warmer temperatures on stratified lakes, and the social context of climate change in Germany.

While creating educational posters, the team looked into important aspects of graphic communication and design. We implemented design elements and appealing art to create informative, yet appealing graphics to catch attention and help understand these concepts better. The elements we considered include color, line, value, space, and shape and how we can manipulate each to match the general theme of the IGB and their online, visual marketing strategy. The team also considered the principles of design such as scale, proportion, unity, variety, rhythm, shape, space, perspective, and depth [34]. In this process, the group researched these elements to understand the meaning of different features, found inspiration from various sources, specifically the IGB website, and used a graphic design software called Canva to illustrate and edit words and shapes. With each iteration of edits, we conducted two sets of interviews with researchers at the IGB to receive feedback for final designs.

We also supplemented our completed background research by conducting interviews to gather information to include in our posters. We identified major stakeholders involved in our project as interview subjects. These stakeholders included IGB employees in both the marketing team and the research team and visitors to the IGB and Lake Stechlin.

We held one in-person and two remote interviews. Whenever possible, we recorded the remote interviews. We held both individual and group interviews. During group, in-person interviews, one team member conducted the interview, one person took notes, and the other two members presented any necessary findings. At the start of each interview, we stated our goals and gave a brief introduction as well as a consent preamble (See Appendix B).

A final series of brief interviews were conducted in order to measure the sponsor's satisfaction with the posters over the course of the project. These interviews followed the same format as previously described. The team asked a number of questions tailored to identify specific recommendations that the interviewees had to improve the overall quality of the posters. For specific interview questions and protocols, see Appendix C.

OBJECTIVE II

USE A PROGRAMMING LANGUAGE TO GENERATE LAKE PARAMETER PLOTS THAT DISPLAY THE STATE OF LAKE PROCESSES THROUGHOUT A WHOLE CALENDAR YEAR

The IGB holds open houses to explain complex aspects of lake stratification to the public. They discuss what stratification is, how it is changing, and why it is changing. The visitors receiving this information are often previously uninformed on the processes that happen at lakes. Therefore, it can be difficult to visualize these complex topics, for example, water temperature changing at different rates for different depths. As a result, we were tasked to draft, develop, and finalize educational material that visualizes lake stratification.

As our target audience is high schoolers, we wanted to emphasize the engagement of our material. A great way to increase engagement is to make the material interactive. Therefore, we decided to develop a program that can display information on the lake such as water temperature, oxygen levels, and chlorophyll levels, displayed at different depths of the lakes. This program outputs a plot which displays these properties over the course of a year. Additionally, the water temperature will be displayed along the depth for each day in a year. This graphic is interactive via a slider with which different days in a year can be displayed.

The program is written with the coding language R. We were given a briefing on the language by a research leader at the IGB, Sabine Wollrab. In the briefing we were introduced to a R package which played a vital role in our program development. At first we were given 3 months of data by the IGB, which we used to start writing our program. On a weekly basis presented our program to the IGB employees Sabine Wollrab and Armin Penske, who gave us feedback. Eventually, we were given a year's worth of data, which is the normal output of the LakeLab. Once we were satisfied with the outputs of our code we used a video editing software that would combine all the plots our code would output into an interactive graphic, adjustable using a slider. This interactive graphic can then be used by IGB researchers and visitors to visualize trends in the Lake.

OBJECTIVE III

EVALUATE THE EDUCATION MATERIAL

The material we created was designed with the intention of being used to educate high school students on processes in Lake Stechlin as well as similar freshwater bodies, given their immense scientific and social significance. For us to gauge the responsiveness and interest of this target demographic, we discussed with the IGB the prospect of conducting focus groups with high school students. As these high schoolers are our target audience, we concluded that they would give us the best possible feedback. Because the Covid-19 pandemic prevented us from communicating more directly with high-school age students, we also prepared to contact Raafat Bachenaq, who worked with the Berlin Project Center, to get into contact with university students living in Berlin. He was able to give us the contact information of multiple students to hold our first focus group with. The members of the focus group were given an introduction as well as a consent preamble before the focus group (See Appendix E). The main purpose of the first focus group was to determine which poster design was the best at appealing to and educating the students. In particular we were looking to gauge their opinion on the usefulness of the content, the efficacy of our design principles, and any potential drawbacks related to visuals for each of the poster designs we presented.

Once we implemented the knowledge gained from our first focus group, we conducted a second focus group with the high schoolers. The focus group held was composed of four to six high school pupils. Parents of these focus groups participants were given an introduction as well as a consent preamble before the focus group. The goal for this focus group was again to gauge the opinion on the usefulness of the content, the efficacy of our design principles, any potential drawbacks related to visuals, and their satisfaction level. This final round of feedback gave us final comments which we implemented at last. For specific focus group protocols and questions, see Appendix F.

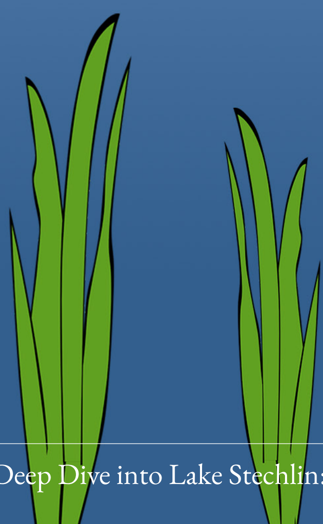
RESULTS

HISTORY AND SIGNIFICANCE OF LAKE STECHLIN

Lake Stechlin is one of the cleanest lakes in Germany. Its name derives from the Slavic name "steklo" meaning crystal clear [35]. The area surrounding this lake has a particularly interesting history, dating back to 12,000 years ago, when the last glaciation carved out the body of the lake. From then, several settlements popped up and disappeared in the Stechlin area, and the remnants of these villages surrounding the lake are still there today. In primeval historical time, the Stechlin area was thinly populated, with each settlement only lasting temporarily [35]. During the Middle Ages, Slavic settlers migrated and founded small villages, but they were then expelled by German conquests. Deforestation during this time led to the development of large, planned villages. In the Late Middle Ages, there was a retrogression of these settlements due to epidemics, wars, and the agrarian crisis [35]. The Lake Stechlin area thus has the greatest portion of deserted villages in Central Europe [35]. Resettlement of these villages began in the 16th century and increased during the 18th century and nearly half of all the deserted medieval villages were resettled [35]

In addition to a long history of glassworking in these villages, fishing remained the leading part of their economy [35]. In the 18th century, the homeowners leased the lake to professional fishermen and they dwelled in fishery houses on Lake Stechlin [35]. In 1898, a solid fishing farm was established near the southeastern shore of Lake Stechlin, which, since 1959, is now the Limnological Laboratory Stechlin, owned by the IGB.

The famous novelist Theodore Fontane made Lake Stechlin and its clear waters popular after visiting and becoming fascinated with Lake Stechlin in September 1873 [36]. In his novel, Der Stechlin, he tells the story of the Red Cock who lived at the bottom of Lake Stechlin and haunted the region. The legend of the red rooster, who comes up to the surface when a fisherman fishes in a place he does not like, is eerie:



> "IT GOES WITHOUT SAYING THAT THE FISHERMEN KNOW IT BEST. HERE THEY MAY CAST THEIR NETS, AND ALL REMAINS CLEAR AND BRIGHT ON THE SURFACE, BUT IT WON'T TOLERATE THIS TEN PACES FURTHER ON, OUT OF PURE WILFULNESS; ITS COUNTENANCE GROWS WRINKLED AND DARK AND A RUMBLE OF ANGER CAN BE HEARD. THEN IT IS TIME TO STEER CLEAR OF IT AND SEEK THE SHORE. BUT IF SOME RECKLESS FELLOW IS IN THE BOAT AND SEEKS A CONFRONTATION, THEN MISFORTUNE FOLLOWS AND THE COCK APPEARS, RED AND ANGRY, THE COCK THAT SITS BELOW ON THE BOTTOM OF THE STECHLIN, AND BEATS THE LAKE WITH HIS WINGS UNTIL IT FOAMS AND SURGES; AND HE SEIZES THE BOAT AND SCREAMS AND CROWS SO THAT IT ECHOES THROUGHOUT THE WHOLE MENZER FORST FROM DAGOW TO ROOFEN, EVEN AS FAR AS ALT-GLOBSOW."

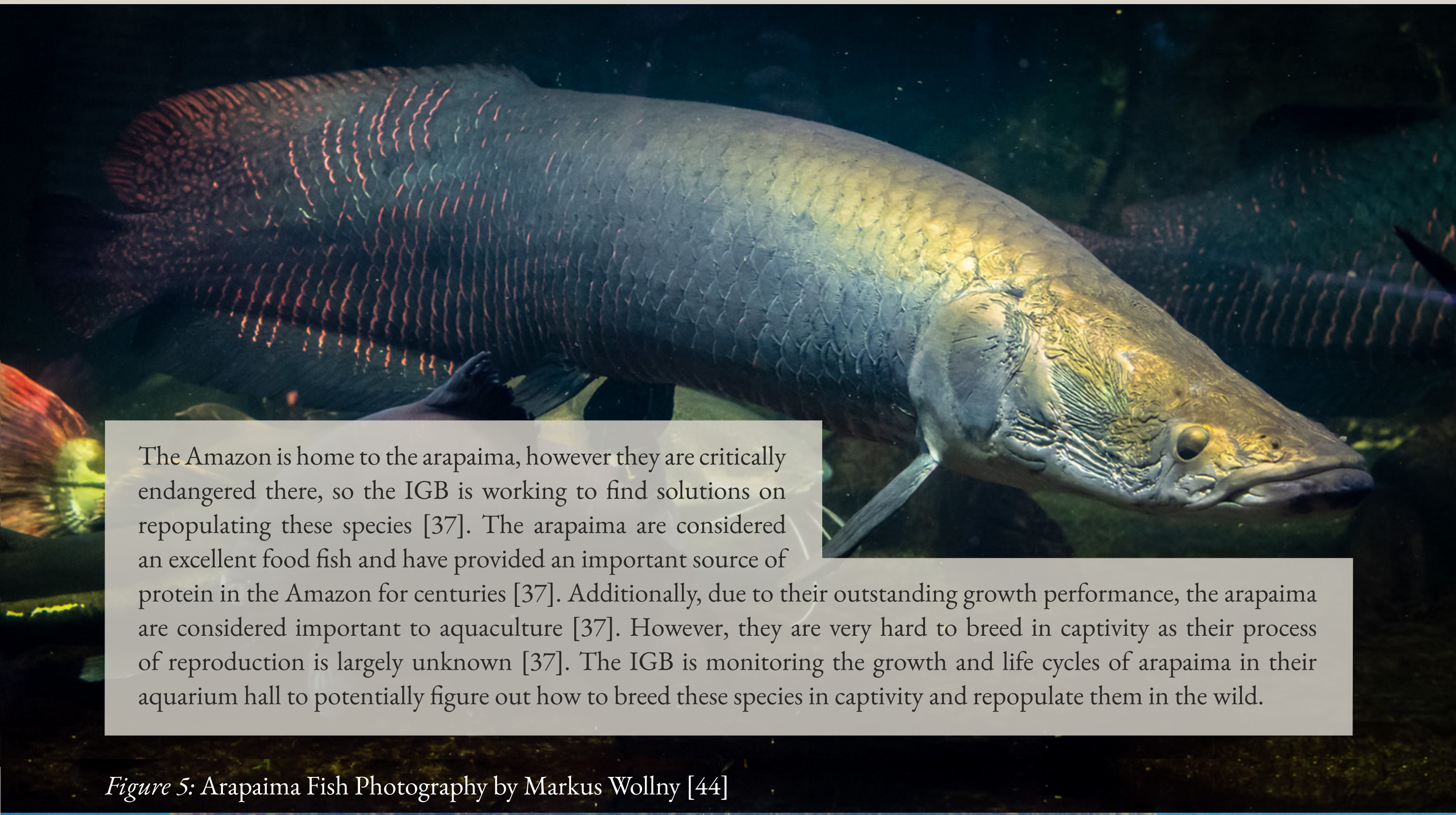
BITAS AUT GENIM

This story is said to be incredibly old and passed down for generations in the Lake Stechlin region. Fontane's description of the reckless fisherman was transformed into the shape and appearance of a rude and savage fisherman named Minack, who is said to have lived in the fisherman's cottage between 1733 and 1826 and allegedly died by drowning in Lake Stechlin [35].

Fonatne's novel had such a great impact on people that a fish species, Coregonus fontanae, is named after him [36]. The Coregonus fontanae is a native fish species that is now endangered as it is exclusive to Lake Stechlin [36]. It is thought to have evolved from the cisco species, Coregonus albula. The Coregonus fontanae is the smallest cisco fish there is in the world.

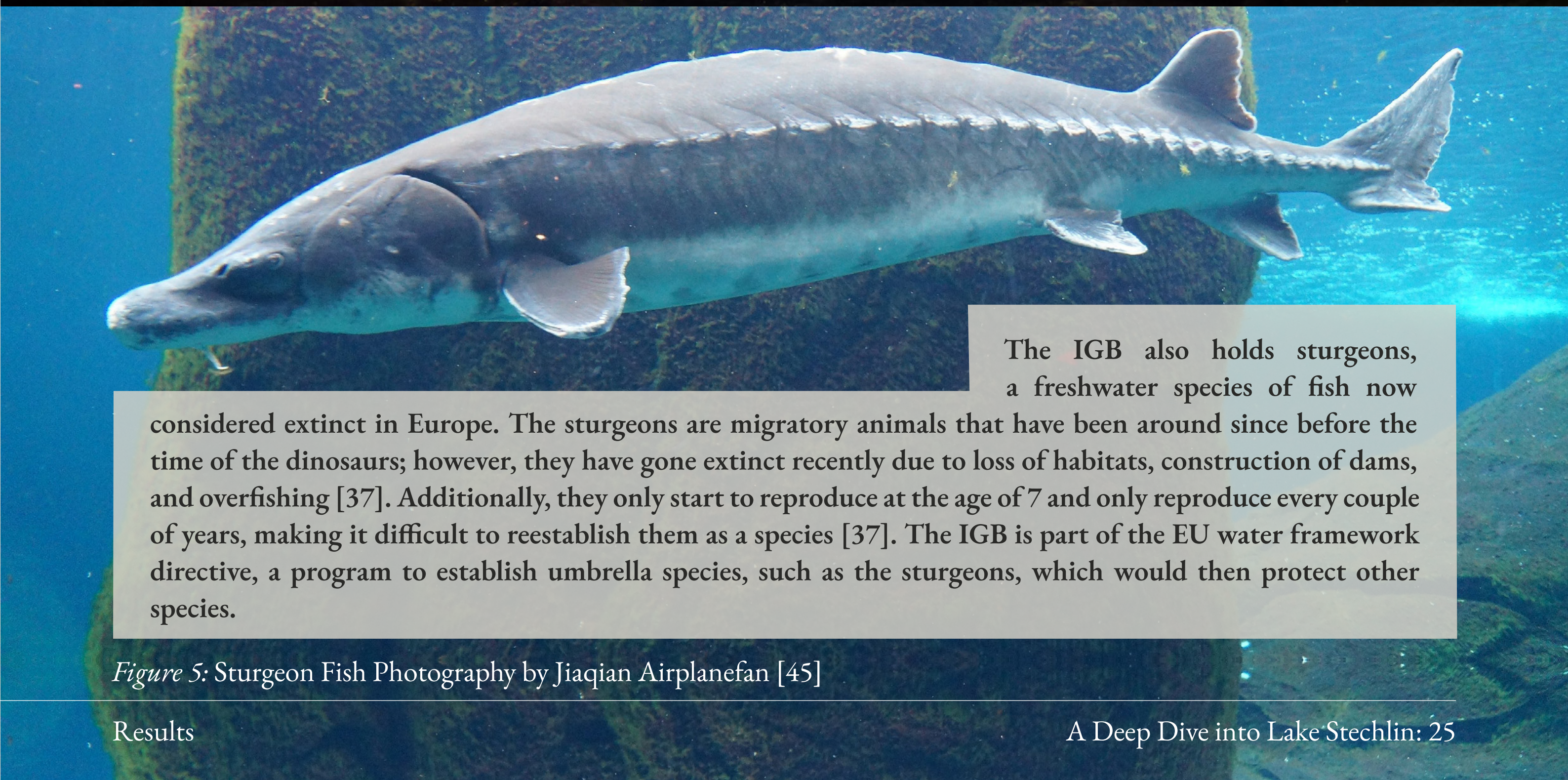
Human-made influences such as extensive clearing and construction of artificial inlets and drains dramatically affected diversity of species in Lake Stechlin, so it was placed under protection in the 1930s. In fact, one of such human-made influences is the Rhiensberg nuclear power plant which operated from 1966 to 1990. The LakeLab was originally founded to research the effects the power plant had on the lake. The construction of this power plant forced the fishermen to relocate and live across the lake [36]. Today, the area is a nature reserve, part of the Stechlin-Ruppiner Land Natural Park. Thus, the fishermen are the only people, besides the IGB, who can operate a motorboat on Lake Stechlin [36].

The IGB was founded in 1992 by the merger of three research institutions: the Institute of Inland Fisheries (IfB), The Hydrology Department of the Institute of Geography and Geoecology (IGG) in Leipzig, and the Department of Experimental Limnology Neuglobsow of the Central Institute for Microbiology and Experimental Therapy (ZIMET). On 1 January 1992, the IGB started its work, with headquarters at Berlin-Friedrichshagen, Müggelsee, and an experimental station on Stechlinsee. The IGB conducts research on freshwater bodies and their biota to predict responses to environmental change. Its office in Friedrichshagen has an aquarium hall where the staff farm fish. There they hold two of the world's largest freshwater fish, the sturgeon and arapaima (Figures 5 and 6), both of which can grow to be 5 meters long.



The Amazon is home to the arapaima, however they are critically endangered there, so the IGB is working to find solutions on repopulating these species [37]. The arapaima are considered an excellent food fish and have provided an important source of protein in the Amazon for centuries [37]. Additionally, due to their outstanding growth performance, the arapaima are considered important to aquaculture [37]. However, they are very hard to breed in captivity as their process of reproduction is largely unknown [37]. The IGB is monitoring the growth and life cycles of arapaima in their aquarium hall to potentially figure out how to breed these species in captivity and repopulate them in the wild.

Figure 5: Arapaima Fish Photography by Markus Wollny [44]



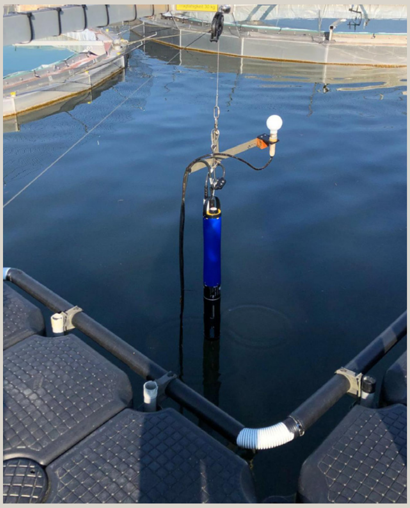
The IGB also holds sturgeons, a freshwater species of fish now considered extinct in Europe. The sturgeons are migratory animals that have been around since before the time of the dinosaurs; however, they have gone extinct recently due to loss of habitats, construction of dams, and overfishing [37]. Additionally, they only start to reproduce at the age of 7 and only reproduce every couple of years, making it difficult to reestablish them as a species [37]. The IGB is part of the EU water framework directive, a program to establish umbrella species, such as the sturgeons, which would then protect other species.

Figure 5: Sturgeon Fish Photography by Jiaqian Airplanefan [45]

Lake Stechlin is a suffering ecosystem and the IGB is working to mitigate the negative consequences done through data collection. To collect data from the lake, the IGB uses multiparameter probes. The multiparameter probes measure temperature, pH, oxygen content, redox potential, electrical conductivity and turbidity. The pigment probes use fluorescence measurements to determine the chlorophyll content of the algae suspended in the water. These probes take readings every 0.5 meters for up to 20 meters multiple times a day and the data is transmitted to the IGB over a fiber optic cable. The temperature, oxygen content, and chlorophyll readings from 2016 and 2019 were used to generate plots on the programming language R that show how climate change has been affecting Lake Stechlin.


Photo taken by Armin Penske

Besides taking data measurements, the IGB conducts several experiments to determine the health of the lake. One of those experiments is a transparency test. One of the transparency tests uses a secchi disk, a viewing cone, and a measuring tape to measure the clarity of the water. A secchi disk is a plain white, circular disk 30 cm in diameter and is mounted on a pole or line and lowered slowly down into the water. While it is slowly lowered, the measuring tape is used simultaneously to determine the depth of the disk. The disk stops lowering as soon as it is no longer able to be seen through the viewing cone and the depth of which the disk is at is read. The average depth that our team could see was 2.6 meters. Armin Penske informed us that this is unfavorable as the expected depth with which the disk should be seen is 10 meters and that this means that there is excess algae at the surface. Fortunately, when taking a water sample from 20 meters deep, the water transparency was very clear, meaning that there are algae blooms at the surface of the water and not the bottom.



Dr. Thomas Gonsiorczyk

Dr. Thomas Gonsiorczyk, a sediment researcher who works in the Plankton and Microbial Department, reinforced that algae blooms were toxic to Lake Stechlin as they release toxins that contaminate drinking water and use up nutrients meant for other species in the lake. Dr. Gonsiorczyk, as part of his work, takes sediment samples from the bottom of Lake Stechlin and analyzes the nutrient concentration in it. One nutrient he monitors is phosphorus. Trends in phosphorus concentrations in the lake in November over nine years displayed that there has been a steady increase of phosphorus in the sediment, which is detrimental to the health of the lake [36]. However, there was not a clear reason why there has been a steady increase. One theory is because the stratification period is longer due to climate change which means phosphorus stays in the deeper waters longer and accumulates over time. He also touched upon how thermal pollution is a factor to consider at Lake Stechlin as it has no external water inlets or outlets (rivers/streams), meaning that phosphorus enters the lake purely through groundwater and has no escape route [36]. This accumulation of phosphorus leads to increased cyanobacteria killing the plants responsible for producing oxygen. Since the lake is stratified for a longer period, this oxygen no longer gets dispersed between the different layers, leading to significantly lower concentrations of O2 in the deeper layers [36]. In fact, oxygen concentrations at different depths of Lake Stechlin since 2012 have been declining, proving his previous point. There has been no oxygen at depths lower than 20 meters since 2017, which is of great concern. To demonstrate his research, Dr. Gonsiorczyk taught us how he takes sediment samples and we were able to bring our sample back to the IGB office located in Muggelsee to analyze the phosphorus concentrations in the sediment.

IMPLEMENTING GRAPHICAL DESIGN ASPECTS TO GENERATE EDUCATIONAL POSTERS

For the IGB to publicize its research on Lake Stechlin, the IGB asked the team to design posters to place around the lake for open-house visits. When designing posters as educational material, it is important that they portray the necessary educational information, while appealing to viewers. Alexandra Lennarz, a graphic design student, states that the first step in the design process is understanding what the project is asking and research on the topic of the project. Then it's followed by pencil sketches, digital sketches, and finally the digital draft. Graphic design facilitates learning by developing a visual concept and effective visual communication [38]. These goals must be accomplished while staying within the limitations of graphic design [38]. Therefore, to tell a compelling story, the designer needs to make the most of the principles of design.

The principles of design are scale, proportion, unity, variety, rhythm, balance, emphasis, gradation, pattern and movement [39]. Scale is the size of one shape in relation to another, and it also refers to people's perception of how big and close some elements are to each other [39]. Proportion is the relationship of elements to the whole image and to each other [39]. It is the feeling that all texts, shapes, lines and colors fit together to create something appealing to the audience [39]. Moreover, unity is the wholeness or oneness of a piece of artwork, and variety is related to diversity or contrast due the use of different shapes, sizes and scales [39]. Other than that, rhythm is a principle of design that indicates movement throughout the plane, balance is the distribution of different objects, colors, and spaces, and emphasis is part of the piece that captures the audience's attention [39]. Lastly, gradation is combining elements in a way that shows slow changes, pattern is the repetition of certain objects or elements in a piece of art, and movement is the path the audience's eyes take throughout the work [39]. These design principles together help in teaching environmental information in a visually interesting way.

According to Lennarz, the most important aspect of effective visual communication in educational posters is that the content is readable. This means that a reader with no prior knowledge of the information looks at the poster, gets hooked and sees something interesting leading to them looking deeper into the topic, and comes away with more information. Another important aspect to consider is being intentional in the graphic and looking at where the user's eye needs to flow [38]. The information needs to flow and be understandable [38].

Nadja Neumann and Angelina Tittman, who are on the marketing team at the IGB, agree that comprehensible and easy to understand language is an important consideration in graphic design. They also state that in graphic design, especially in poster design, there needs to be a good relation between text and image with an eye-catching headline. Tittman also mentions that many great posters have an option such as a QR code that leads the reader to more information on the subject, if they desire.

Distribution of educational posters was another thing to consider when designing our posters. Tittman shares that the animation of the plots and posters can be displayed on their website and on their communication channels as well as within the network of leibniz associations which have strong connections to schools and educational centers within Berlin. Within each district there is a person responsible for environmental education.

When designing our posters, we employed the design process and the design principles in our posters in various ways. We began with rough drafts and sketches of our images and then finalized our images digitally on Photoshop. In implementing design principles, for example, we implemented emphasis in the lake stratification poster by making the seasonal lake diagrams bigger than the density and the oxygen graphs, since the team wants that part of the poster to catch viewers' attention. Moreover, the team integrated scale and proportion with different text box sizes, and the graphs related to temperature, oxygen, and chlorophyll on the lake stratification poster. Nevertheless, in the other two posters related to eutrophication and climate change, the team integrated balance and movement through our landscape diagram explaining the algae bloom cycle and through the flow chart concerning increase in blooms and decrease in dissolved oxygen depletion. Overall, the posters had proper use of unity since all of the elements and objects fit together cohesively and there is efficient use of harmony and variety.

The need for environmental education, as expressed by Dr. Sabine Wollrab and Armin Penske, was an important consideration in designing our posters. In general, environmental graphic design on posters or infographics include key elements such as a title, graphics, text, white space, layout, flow and color [40]. Graphic design in posters related to environmental education or awareness should contain multiple aspects to catch viewers' attention. With that, it should connect with the audience, contain a message that will stay in readers' minds, include a picture that highlights the main point of the design, and showcase the authors' integrity [41]. That integrity should be related to the print and the work the company is doing as a whole. Our posters focused on how climate change has negative consequences on lakes, with plots on the changes in temperature and oxygen levels in Lake Stechlin over the years to give a real-life example. According to The Climate Reality Project [42], almost 50 percent of a person's brain is involved in visual processing, and a good poster has a beginning, middle and end. One example, "World Bank: Climate Extremes, Regional Impacts, and the Case for Resilience," describes the global effects of climate change such as rising global sea levels, declining drinking water, and increasing global temperatures (Figure 7). Next, the poster gets into more details in case studies on the impact of climate change, and then lastly, it ends on a hopeful note about what people can do in the long run. With paragraph text and information, too much of it would make people lose interest, and too little would not make the audience informed on the subject matter. One way of creating balance between images and information is through linking cause and effect aspects together such as the connection between changes and people's everyday habits.

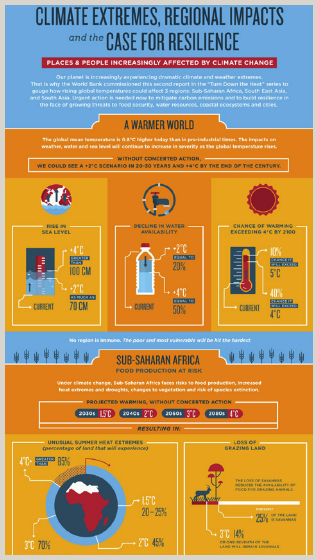


Figure 7: Part of the World Bank Poster

Environmental education topics can be developed from the attention certain issues get from communities. In an article published by individuals in the United States Department of Agriculture [43], the rise of atmospheric temperature is a first order impact, while issues relating to the freshwater crisis is a fourth order impact. For example, inspiration was also drawn from a NASA Infographic: Earth's Carbon Cycle is Off Balance (Figure 8). The poster links the atmosphere, land, and ocean together in relation to carbon dioxide and its effects. The infographic includes information in both paragraph text and bubbles on relatable background images, and the texts flow from one aspect to another, showing an overall cause and effect relationship. It also includes a brief statement on a dangerous milestone that carbon dioxide has passed, which gives viewers a sense of urgency about the topic.

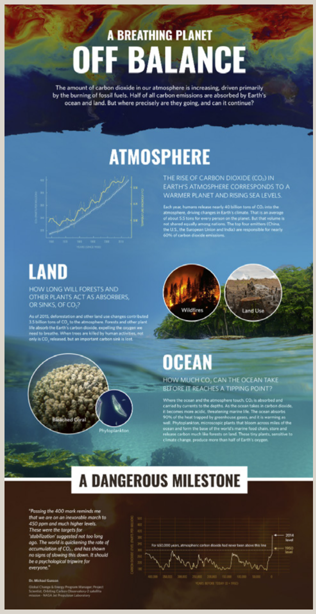
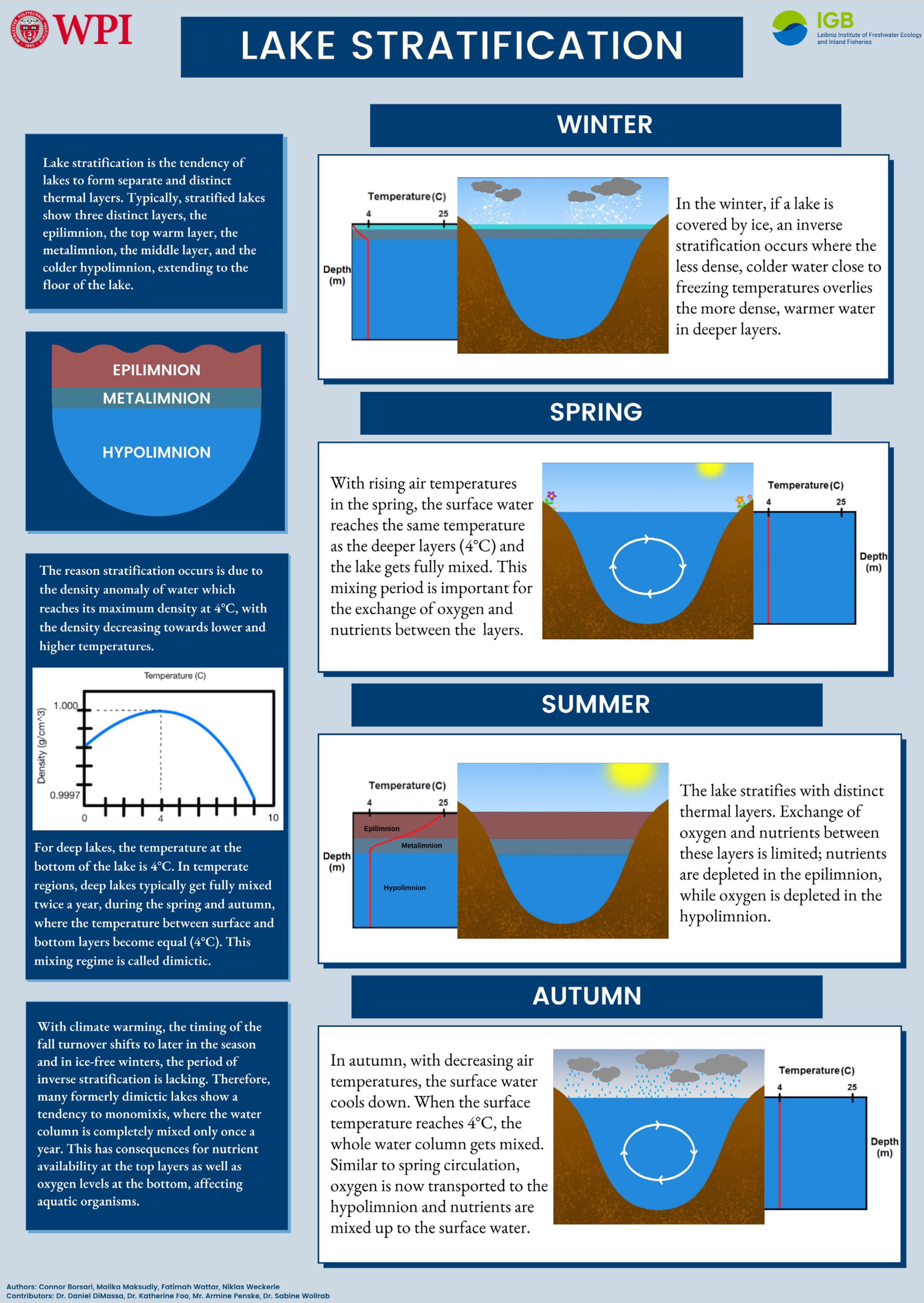


Figure 8: NASA Infographic

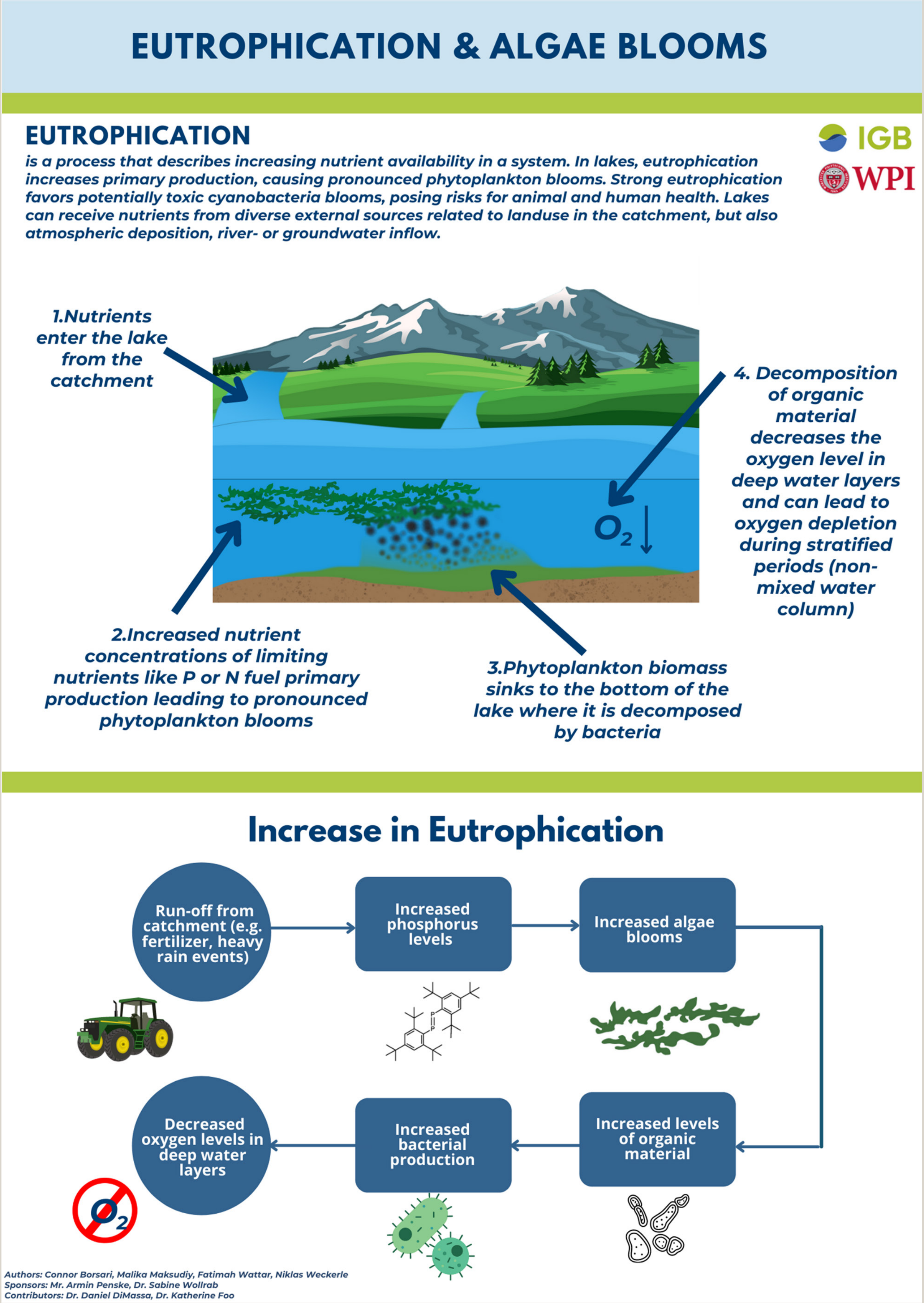
In developing our posters, we employed the above design principles within the parameters set by our sponsors, which included specific symbols and colors used to explain stratification. Through an iterative feedback process, our sponsors guided the poster design toward greater environmental accuracy and educational value. They wanted to be sure that the scientific processes explained in the posters were clear, precise, and accurate, so as not to misguide people. Dr. Wollrab's advice on the Lake Stratification poster was to include more detail in the stratification process in the different seasons. Specific feedback on the lake stratification poster can be found in Table 1, Appendix G. Revisions were aimed to connect different features of lake processes together. One of those features includes the relationship between stratification and the density of water at varying temperatures to show why warmer water is at the surface. Another characteristic to edit was the link between general stratification and the specific stratification in Lake Stechlin which can be seen when plots generated from R coding are included in the posters. These plots show the water temperature and oxygen concentration along different depths at different times of the year which ultimately show the pattern of changes in those parameters over time.

Nonetheless, our sponsors' feedback regarding eutrophication and climate change aimed to bring multiple issues and steps together in a direct way. This is because it is important for high school students to understand it without numerous environmental aspects since that would be too much detail. With that, revisions were focused on landscape diagrams and the flow of descriptions or steps around the poster. Specific feedback on the posters can be found in Table 2 and Table 3, Appendix G. As a result of those revisions, the viewers' eyes could move from one diagram to the next so that the audience can fully understand the portrayed concepts in the long run. For more educational value, Lennarz suggested using one serif type font for the body text and a different font for the title. Serif typefaces are generally better for the body text as it helps the reader's eye move through the lines. Small things like fonts, she said, can make big differences.

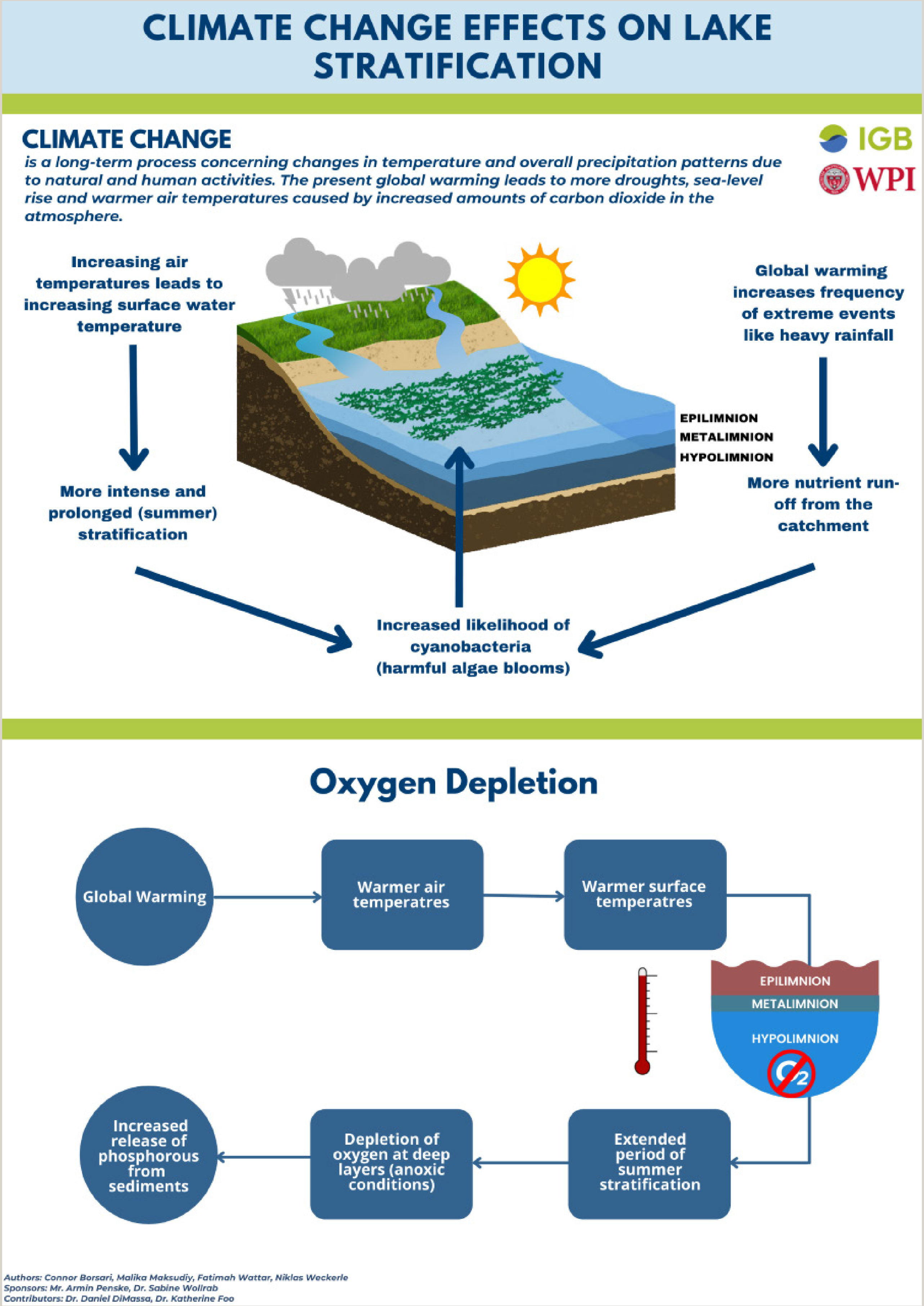
FINAL LAKE STRATIFICATION POSTER



FINAL EUTROPHICATION & ALGAE POSTER



FINAL CLIMATE EFFECTS ON LAKE STRATIFICATION POSTER



FOCUS GROUPS

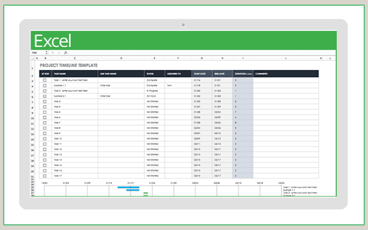
Feedback was also secured through a focus group conducted with four graduate students, who had little to no prior knowledge of lake stratification. Their feedback mostly focused on the layout of the posters. All participants liked the layout and color scheme of the Lake Stratification poster and agreed that the blue background matched the topic of lake stratification. Participants B and D wanted more information on the thermal profile graphs and suggested adding units to the graph for clarity. All participants agreed that the R-coded plots on the left side were unclear, and they did not understand its purpose. Participants B and C even remarked that they skimmed over it and did not really look at them. They suggested adding a description explaining what it meant. Participant D suggested making the left and right side of the poster more connected as they felt that there was currently a disconnect as if they were two separate posters. Participant D also remarked that usually, people look at the left side first and they felt the information on the right side was more informative and should be looked at first. Participant C suggested making the stratification seasons more centered to balance the elements on the left and right side out. Participants B and D really liked the pictures of the lakes and thought it helped them to learn more about the different seasons. Because of the feedback received on the plots, our sponsors and we decided to remove the plots as they were too difficult to explain on one poster.

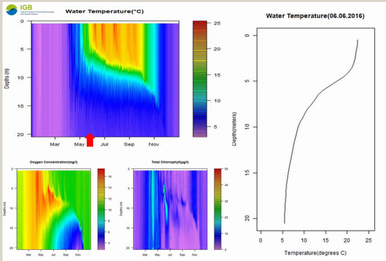
On the Eutrophication poster, all participants liked the layout and color scheme of the poster. They also liked the text-to-image ratio and did not think more text was needed. Participant D thought the image should be flipped so that the numbering starts on the left side, rather than the right, since everyone begins reading on the left side. Participants C and A were confused on how the increase in eutrophication begins with agricultural practices and ends in oxygen depletion and suggested making the connection more evident, either by adding arrows or more elements between the two. All participants thought the overall material was understandable.

The focus group also gave additional feedback on the layout of the Climate Change Effects on Stratification. Participants A and D were confused on what the numbering of 1 and 2 mean on either side of the diagram. They suggested removing the numbering since numbering suggests ordering and the information was not meant to be ordered. They also suggested using the same wording and font size throughout to make the overall look of the poster nicer. Participant B suggested making the color scheme of the poster blue so that it would match the topic more. Participant D also suggested adding colors to the diagram to differentiate between the layers of the lake and to make the layers all the same colors between the different posters, so that it is all more uniform and easier to follow.

PLOTTING LAKE STECHLIN DATA

In order to generate animated plots from data collected at Lake Stechlin, we first needed to identify a programming language that is functional and accessible to a large demographic. We needed to use a programming language with graphing capabilities that can visualize data collected at Lake Stechlin in an appealing way. The IGB continuously collects data on Lake Stechlin, which is then stored in Excel sheets. These sheets, though they contain considerable detail, are difficult to comprehend for the average person. Therefore, we wanted to write a program which can plot this data on a coordinate system. These data plots, connected with posters we made, present the complex data collected by the IGB on lake stratification in a simple, easy-to-understand way.





We chose to use the language R because R is capable of dealing with large elaborate tables of data while avoiding the use of some unnecessary traditional programming steps. R is designed specifically to intuitively access specific sections of tables, a feature which helped the team to break the data into the multiple unique plots requested by the IGB without needing to manually break the data into sections prior to plotting. Additionally, R is more accessible to both IGB employees and the public. R is an open-source product, hence it is free to download for anyone.

Though we ended up choosing R, our original thought was to use MATLAB because a multi-paradigm programming language such as MATLAB is ideal for reorganizing large amounts of data. Additionally, MATLAB has a number of intuitive plotting tools that would have been ideal for making the lake data plots. The team was familiar with MATLAB as all of us had experience with it in the past and knew the basics of the language. That being said, if we had decided to utilize MATLAB for this project, we would have needed to assume that anyone who intends to use the tool we created has access to MATLAB. This piece of software is not free, which means that the general accessibility of the team's final product would be impacted. MATLAB, unlike R, has a license cost, and depending on the type of usage the license cost varies and can be expensive. Since R is an open-source language, it has a lot of community support for development and documentation. Additionally, the RStudio Package requires very little computer processing power and can be run on fairly low-end machines. In the case of MATLAB this program does require a greater amount of processing power further limiting its accessibility.

Once we decided upon using the code language R, we were briefed on the language by a research leader at the IGB, Sabine Wollrab. In the briefing we were introduced to R packages such as 'rLakeAnalyzer'. This package, shown in Figure 9, added plotting capabilities specific to lake parameters in terms of depth and time which was eventually used to create the three-dimensional plots seen in the team's final animation.

We used this code and expanded on it in order to turn our inputs into the desired outputs. The inputs are data within Excel spreadsheets including date and time, depth of reading, temperature, oxygen concentration, and chlorophyll concentration. Our program can intake a year's worth of data, and accounts for the lack of data collection on certain days, or weeks, due to maintenance or other issues.

Package 'rLakeAnalyzer'

June 9, 2019

Title Lake Physics Tools

Maintainer Luke Winslow <lawinslow@gmail.com>

Version 1.11.4.1

Author Luke Winslow, Jordan Read, Richard Woolway, Jennifer Brentrup, Taylor Leach, Jake Zwart, Sam Albers, Doug Collinge

Description Standardized methods for calculating common important derived physical features of lakes including water density based based on temperature, thermal layers, thermocline depth, lake number, Wedderburn number, Schmidt stability and others.

Depends R (>= 2.10)

Imports plyr, stats, graphics, utils, grDevices

Suggests testthat, knitr, rmarkdown

License GPL (>= 2)

Repository CRAN

BugReports https://github.com/GLEON/rLakeAnalyzer/issues

Date/Publication 2019-06-09 18:45:46 UTC

RoxygenNote 6.0.1

VignetteBuilder knitr

NeedsCompilation no

Figure 9: Original 'rLakeAnalyzer' package

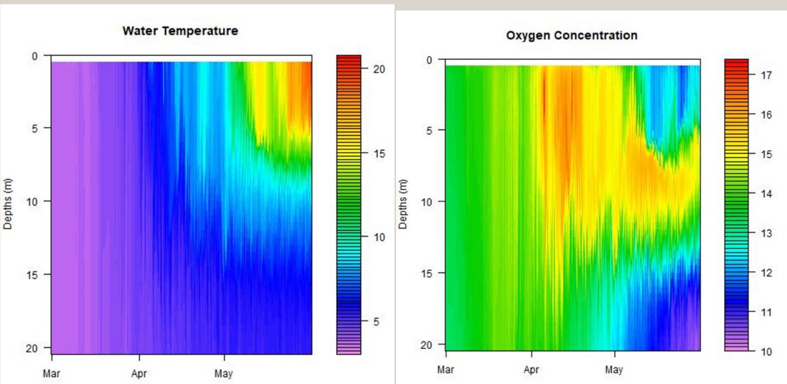
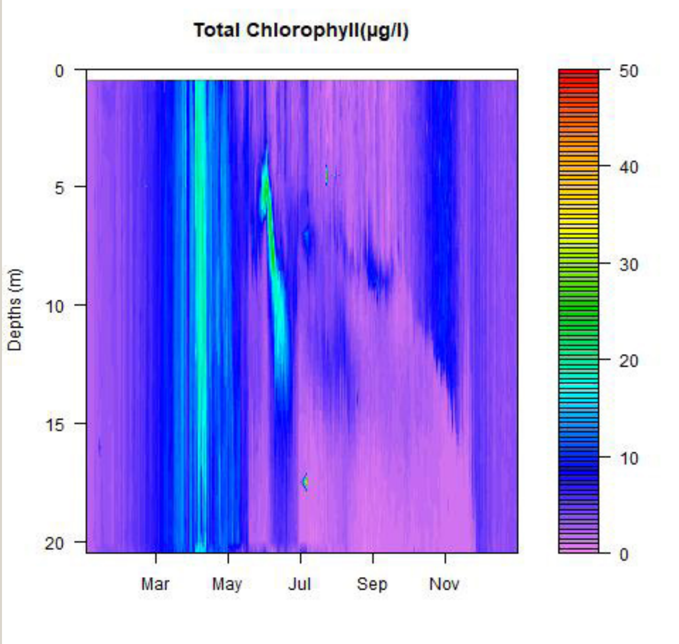


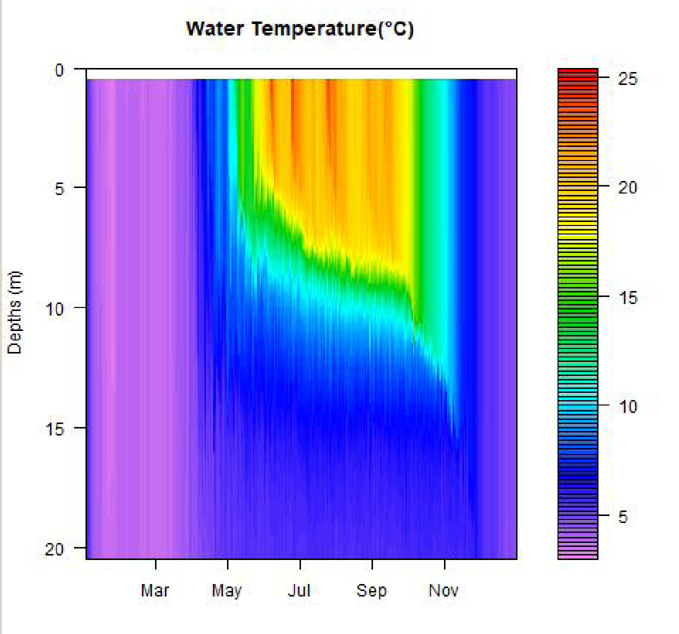
Figure 10: Oxygen concentration and water temperature graphs

The program outputs temperature, oxygen concentration, and chlorophyll concentration at different depths and days throughout a whole year. The graphs, shown in Figure 10, are three dimensional, with different months on the x axis, different depths on the y axis, and the different temperatures, oxygen concentrations, or chlorophyll concentrations represented on the coordinate system using a color scale.

Additionally, the program generates daily averages for each day of the different temperatures at different depths. These plots are two dimensional with the depth represented in the y-axis and the temperature represented in the x-axis. All the plots generated are then morphed into one interactive graph which can be adjusted using a sliding arrow. When the arrow moves, it shows different days according to the order they appear in the year. This graphic therefore illustrates the mixing of the water due to stratification.

The data plots our team developed brought up a variety of challenges we needed to overcome. The data provided to us from the IGB, or specifically the LakeLab, which is where the data is collected, was in csv file format (csv files can be opened in excel in a spreadsheet format). The default csv file contained a large amount of unnecessary cluttered text at the head of the file including titles, dates, and descriptions. For the purpose of plotting all that was needed was the titles of each column and their corresponding data points. Additionally, there were several columns that included redundant data that were removed altogether. If any of this information was included in the csv when it was accessed by the R program errors would be thrown so it was essential that the .csv be cleaned up in advance to be used to generate plots. With the csv file in check the next step in the plot generation process was to break the data apart by depth rather than by date. This is achieved through the use of a built-in R function. Complications arose in this part of the programming process as the ‘rLakeAnalyzer’ requires very specific column titles in order to properly recognize the data. To work around these issues the program was written to retitle all of the columns of data after being broken apart using the R function. With the data being correctly organized and labeled the final step was to reverse the order of the data points provided by the LakeLab. The ‘rLakeAnalyzer’ expects that the input data will be in an increasing order on both the depth and time axes. Similar to the previous issues this was resolved using a series of built-in functions but was an essential step in preventing program errors. The final issue that arose in the R code plotting process involved discrepancies in the provided data. The date and time was provided by the LakeLab for each measurement taken by its probes. A number of these dates became problematic as the time stamps were corrupted in the reorganization process. These corrupted timestamps meant that ‘rLakeAnalyzer’ was incapable of identifying what order said data points should be plotted in. Given the need for the data to be in an increasing order this created a serious issue in the plotting process. To combat this issue a separate program was written to scan through the provided data for data points missing their timestamps. The problematic points were then purged from the dataset in order to avoid discrepancies. With this issue resolved, all of the provided data was in a format that could be effectively plotted. The remainder of the R program included the steps required to take the average of multiple days’ worth of measurements used in the daily profile plots, a process independent from the ‘rLakeAnalyzer’ package.





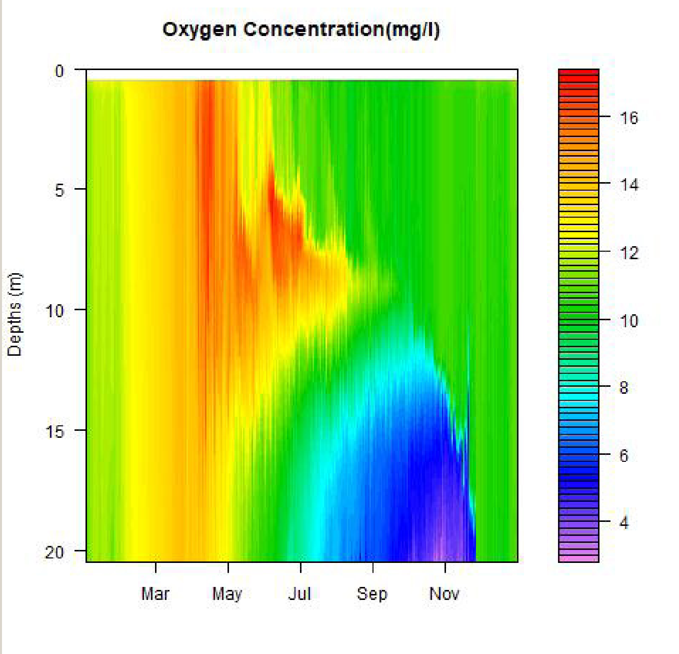


Figure 11: QR Code to animation

From this code the team produced all of the necessary plots which we used in our animation. This animation was ultimately uploaded to the IGB YouTube channel and can now be viewed on this platform. This animation was produced using a piece of video editing software known as Davinci Resolve which is free to download and could easily be used to update said video with more current plots in future years. The animation can be found using the QR code in Figure 11.

This animation includes all of the plots that were discussed previously in this discussion together. The plot seen to the right of Figure 12 labeled Daily Water Temperature is the main changing aspect of the animation. This plot displays depth vs. temperature data for a specific day of the year which is indicated by the red arrow (on the x axis) in the three dimensional Water Temperature(C) plot to the left. In addition to this changing daily temperature plot the upper right corner of the animation includes an image of Lake Stechlin which changes to match the season as the animation moves through the year. In regard to the remainder of the animation the three-dimensional yearly oxygen and chlorophyll plots remain stationary for the entire duration of the animation. These plots were generated using the same years data set but always display the year's data as a whole rather than in steps like the Daily Water Temperature plot. The final element that we included in this animation was a still image of the multiparameter probe. All of these plots together summarize an entire year of, IGB collected, data on various Lake Stechlin parameters. Lake Stechlin parameters.

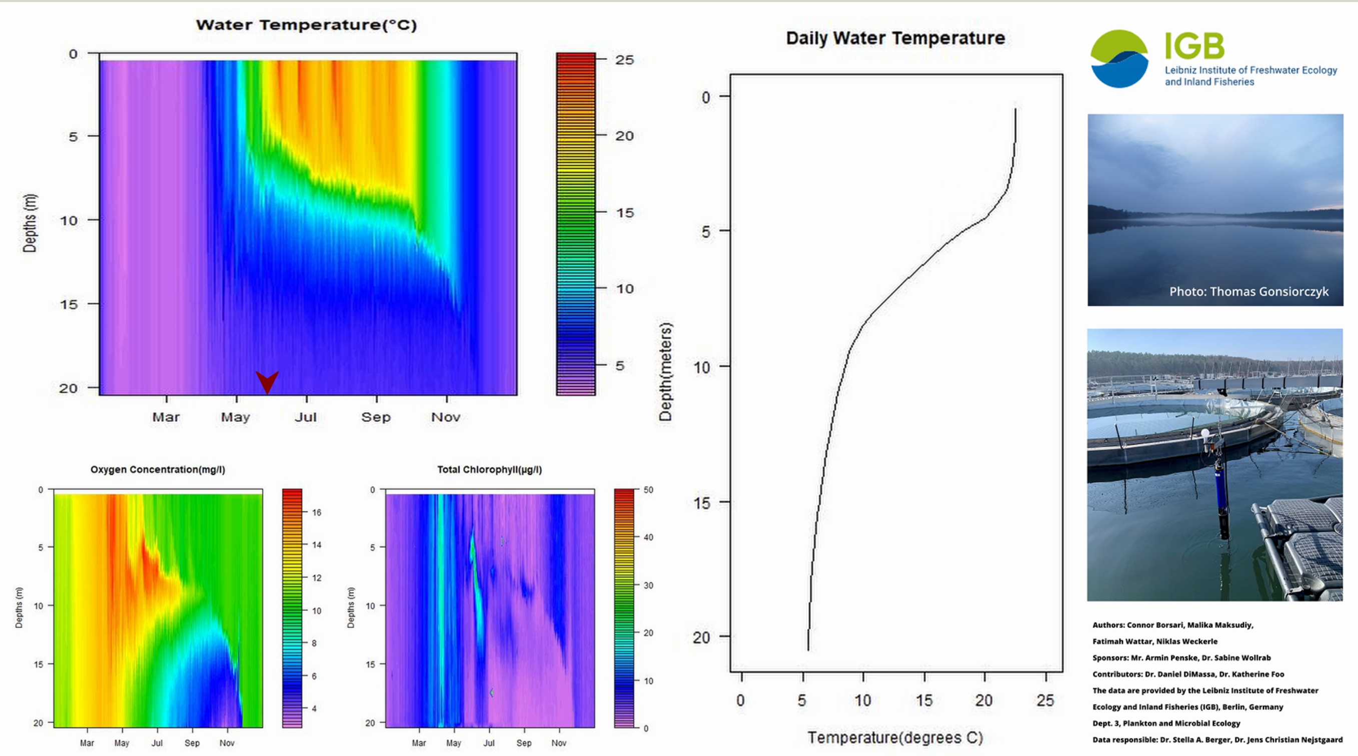


Figure 12: Frame from Animation

Supplementing the program for ease of use

Although one of the team's main objectives was producing this animation, an even more important aspect of the final product was that it could be easily reproduced by IGB employees with new data in the future. In order to help guide the IGB employees that may make use of the team's R program in the future we compiled a 26-page manual. This manual included a number of helpful sections related to things such as data preparation, step by step instructions, and even troubleshooting. Accompanying each section were a number of useful visuals to help guide the user through each step and section. In the troubleshooting section of this manual, a number of issues that the team identified as likely to recur were dissected. Each of these issues was given its own subsection that provided explanations of these issues as well as step-by-step solution instruction. In one case one of these subsections included some additional R programming which could aid the user in resolving the issue. Ultimately, the manual, the organized lake data, the animation, and the R program were all compiled together into a convenient zipped folder which was provided to the IGB for future use.

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31- We spoke with Hauke Daempfling (Hauke Daempfling, lives in Friedrichshagen, Berlin, Germany, personal communication, March 2022) about how tourism plays a role for people living close to Lake Stechlin.

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