Mid-evaluation

Impact of recreational fishing pressure on the catchability of the piscivorous fish species pike *(Esox Lucius)* and perch *(Perca fluviatilis)* assessed via catch-per-unit-effort in an experimental lake fishery

Mid-evaluation analysis

Manu Corver

Mid-evaluation
Catch drop angling experiment

Analysis of the mid-evaluation of the angling experiment within the Predator Project

Date: xx June 2025

Autor:
Manu Corver
Applied University Aeres Almere
Arboretum West 98, 1325 WB Almere
3040832@aeres.nl

Internship supervisor Applied University Aeres Almere:
Sander Harting
Arboretum West 98, 1325 WB Almere
S.harting@aeres.nl

Internship supervisor IGB Leibniz Institute of Freshwater Ecology and Inland Fisheries:
Prof. Dr. Robert Arlinghaus
Müggelseedamm 310, 12587 Berlin
Robert.arlinghaus@igb-berlin.de

SOCIAL - ECOLOGICAL FISHERIES RESEARCH

IGB Leibniz Institute of Freshwater Ecology and Inland Fisheries

HUMBOLDT-UNIVERSITÄT ZU BERLIN

AERES UNIVERSITY OF APPLIED SCIENCES ALMERE

Acknowledgements

As part of my 10-week internship abroad during the third year of my Applied Biology studies at Aeres University of Applied Sciences in Almere, I completed this research report. Working on this report has helped me to further develop my research skills by critically approaching a scientific question within freshwater fisheries. The experience I gained during this internship will support me in my academic and professional development.

Throughout my internship, I was supervised by Prof. Dr. Robert Arlinghaus, to whom I would like to express my sincere thanks for his professional guidance throughout the process of data analysis and report writing. I also want to thank Dr. Ryo Futamura, who supervised me in the field and helped with data visualisation and figure creation.

During the fieldwork, I collaborated closely with several bachelor students: Tammo Steincke, Maximilian Roederer, Malte Bochow, and Leander Bourlakos. I would like to thank them for their teamwork, help with data collection and the pleasant cooperation.

I am also grateful to the IGB Leibniz Institute of Freshwater Ecology and Inland Fisheries for making this international internship possible.

This internship gave me valuable insight into research practice within freshwater fisheries, which I have found highly inspiring. It has deepened my interest in the field and helped me to grow both academically and professionally.

Thank you very much, I look forward to any potential future collaboration.

Table of contents

1. Introduction

Most freshwater fish populations are heavily exploited by recreational fishing. Intensive recreational fishing when lethal will reduce the biomass and size-structure of exploited populations (Lewin et al. 2006). However, even purely non-consumptive recreational fisheries, based on the practice of catch-and-release of all captured fish, can affect exploited populations via unintended hooking mortality (Arlinghaus et al. 2007) and through hook avoidance learning that reduces the reactivity of the fish to the angling gear (Arlinghaus et al. 2017a,b). Multiple studies have shown that the catchability and therefore the catch rates of angling-exploited fishes drop after heavy exposure to fishing (e.g., Beukema 1970; Kuparinen et al. 2010; Wegener et al. 2017; Lucas et al. 2023). Reduced catch rates due to hook avoidance learning have a double negative impact, firstly on catch-dependent angler satisfaction and secondly on the ability of researchers to assess the state of fish stocks (Alós et al. 2019; Roser et al. 2024). Hook avoidance learning has been reported in standardized laboratory and pond experiments in temperature piscivorous fish such as pike (*Esox lucius*) (Beukema 1970; Lucas et al. 2023), and field experiments in previously unexploited piscivorous fish have similarly reported rapid declines in catch rates after the onset of fishing (van Poorten and Post 2005; Wegener et al. 2018; Roser et al. 2024). However, comparative studies like the one by van Poorten and Post (2005), which started to angle on stocks of trout that were previously unexploited, have the limitation of a fully controlled setting because the catch decline in previously unexploited lakes was compared to exploited systems that have experienced uncontrolled angling by the angling public. It is therefore unclear, how fast and how pervasive a possible catch drop in response to fishing pressure is in the wild. Similar concerns can be raised about studies that compared catch rates or reactivities of fish to angling gear in protected areas compared to areas outside that are open to fishing (e.g., Alós et al. 2015; Roser et al. 2014) because of the possibility of past fishing pressure exerting impacts on fish behaviour also in protected areas and because fished and unfished sites could be connected via dispersal of naïve fishes from protected sites to fished sites (Januchowsky-Hartley et al. 2013). To provide conclusive evidence in field settings, fully controlled experiments are needed to showcase the speed and severity of catch rate declines to non-consumptive recreational angling. In my internship I was involved in conducting such a unique study in a pair of small research lakes in north-eastern Germany.

The aim of the present study was to investigate the impact of intensive non-consumptive recreational fishing based on total catch-and-release of all captured fish on the piscivorous fish species pike and perch (*Perca fluviatilis*). By examining the potential for catch-rate reduction, the research sought to understand how adult pike and perch respond behaviourally to increasing recreational fishing pressure. The data in this report present a mid-term evaluation half way through an ongoing experiment that includes both baseline (before) data and intermediate (mid) data in an unexploited control lake and a treatment lake, covering a one-month period of intensive fishing as experimental intervention on half of the lake of the treatment lake. The presented data allow for an early assessment of changes in bite and catch rates over time in the treatment lake compared to control sites. The final (end) data will be analysed and presented in the bachelor thesis of Maximilian Roederer, where an exposure of approximately two months of heavy angling pressure will be analysed. The findings will contribute to a better understanding of predator fish behaviour under exploited conditions and support recommendations for sustainable fisheries management.

The research sought answers to the following leading research question:
'How does a one-month period of intensive recreational fishing based on total catch-and-release affect the catchability of the piscivorous fish pike and perch in a small lake?'

2. Hypothesis

Based on previous studies (Beukema 1970, Kuparinen et al. 2010, Arlinghaus et al. 2017b, Lucas et al. 2023; Roser et al. 2024) it was hypothesized that the catchability of the piscivorous fish species pike and perch will decrease over the course of one month of intensive angling pressure where many fish (Klefoth et al. 2011) are exposed to the private experience of catch-and-release (Czapla et al. 2023). The decline is expected to result from the species' learning abilities, whereby individuals associate capture with a negative experience and thereby learn to avoid artificial lures (Lucas et al. 2023).

3. Method

The presented research was based on a fully controlled angling experiment taking part in two small research lakes in northeastern Germany. This section describes the study site, the experimental design, sampling methods, the time frame of the study, the procedures for catch processing, and the data analysis approach.

3.1 Study site and experimental design

The research was conducted at a small freshwater lake called Kleindöllner See (N 52°59'40.1, E 13°34'55.2), located in Eastern Germany and nearby lake Großer Vätersee (N 53°00'17.0, E 13°33'10.3). The lakes are small, mesotrophic to slightly eutrophic. Kleindöllner See has a size of 25 ha and a mean depth of 4.1 m with a maximum depth of 7.8 m (Klefoth et al. 2011). Großer Vätersee has a size 12 ha and mean depth of 5.2 m with a maximum depth of 11.5 m (Schulze et al., 2006). Both lakes are surrounded by reed belts and offer several batches of submerged macrophytes nearshore. All pike and perch individuals present in the lake are naturally recruited and resident and cannot migrate beyond the lake's boundaries. The fishing rights are owned by the IGB Leibniz Institute of Freshwater Ecology and Inland Fisheries since 1992, and the lakes are used since this time as research site for ecosystem-based fisheries research (e.g., Klefoth et al. 2011; Arlinghaus et al. 2017b). IGB holds the exclusive fishing rights to the lake, meaning it is the only entity permitted to conduct fishing activities there. Großer Vätersee has never been fished by experimental angling since 1992. Lake Kleindöllner See has seen past experimental fishing studies (e.g., Kuparinen et al. 2010; Klefoth et al. 2011), but the last heavy fishing happening in the study lake targeting pike is from a study by Klefoth (2007) more than 15 years ago. As pike only live about 12 years, we can be very sure the current pike population was naïve against fishing pressure. As pair of unfished lakes with no or very limited external disturbance, both lakes offer a controlled environment in which fishing pressure is exclusively induced by the research team, ensuring that no recreational or external fishing activities had an influence on the results. Kleindöllner See served as the treatment lake and Großer Vätersee as an unfished control (Fig. 1). In addition, within Kleindöllner See, the northern side of the lake was declared a no-fishing protected area, generating also a treatment vs. control pair of sites in Kleindöllner See. Only the south side of Kleindöllner See was subjected to experimental recreational fishing to allow for a comparison between the heavily fished southern section and the untouched northern section within Kleindöllner See (Fig. 1A) The north side of Kleindöllner See was treated as an undisturbed nature reserve. Further comparisons were made with the entirely undisturbed Großer Vätersee (Fig. 1B), which was only fished occasionally for a total of six sampling days at the start and the mid-term evaluation for this research. Großer Vätersee also was separated into a north and south part, and was used to examine relative trends in catch per unit effort (CPUE) unrelated to heavy fishing. Inclusion of this lake in the research design was important to control for possible time-dependent trends that varied among the north and the south side of both lakes. Großer Vätersee is used for recreational purposes by local residents (e.g., swimming), but angling permits are not issued. As with Kleindöllner See, the IGB holds the exclusive fishing rights to this lake. Some mild illegal angling cannot be fully excluded, but the Großer Vätersee can in genal be considered unfished and therefore was an excellent control system used to examine the impact of fishing treatment in the Kleindöllner See over time.

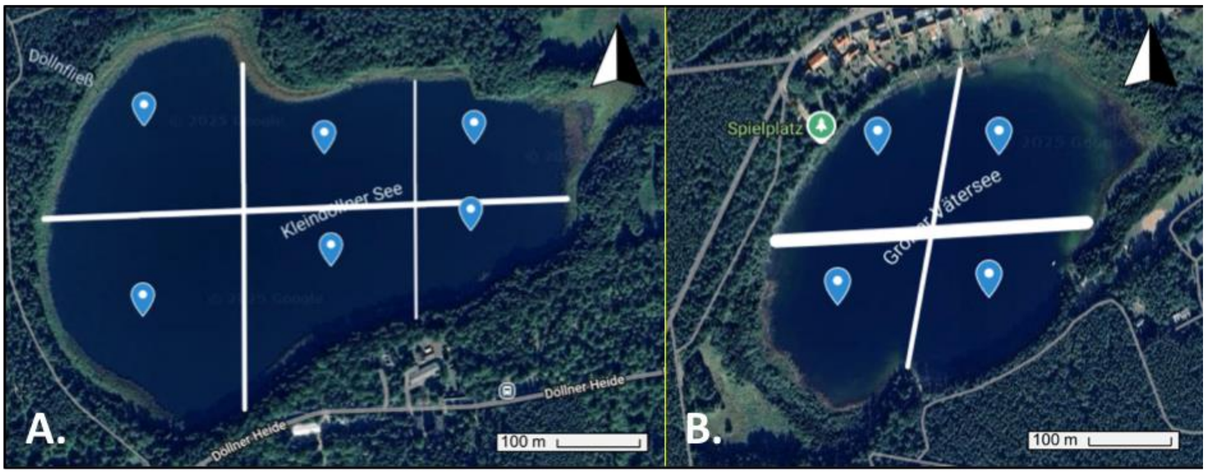

Figure 1. A. Satellite picture of Kleindöllner See; B. Satellite picture of Großer Vätersee.

The study design followed a before-after-control-impact (BACI) design where inference about the impact of the fishing treatment was derived from the "difference-in-difference" in catch rates in the northern and southern Kleindöllner See vs. Großer Vätersee over time. Such designs are necessary to control for temporal change in catch rates unrelated to the fishing treatment, which needs comparisons over time in catch rates in fished and unfished controls. The northern part of the lake Kleindöllner See was added as a separate control site that was unfished, but fish may exchange from the south to the north side. Therefore, comparative assessments of catch rates in the north and south of Großer Vätersee over time helped control for any directional movement of fish over time. For pike, previous work in Kleiner Kleindöllner See has shown that the fish are resident in a confined home range and rarely cross the lake borders (Kobler et al. 2008), a pattern that cannot be assumed for perch (Nakayama et al. 2018). Therefore, from a perspective of experimental design the most robust insights could be derived from changes in catch rate in pike in Kleiner Kleindöllner See on the southern side as the fishing on the southern Kleindöllner See would heavily impact the pike resident there, leaving the pike on the north side untouched so that changes in catch rates over time in both sides and relative to pike in Großer Vätersee would be suitable to test the study hypotheses.

3.2 Sampling method

Fishing was conducted from a boat with rod and line and with three standardized lures (shad, chatterbait and dead natural perch fished with a Drachkovitch system) with both occasionally natural colours and mostly unnatural colours. The specific lure types are shown in Table 1 and also visible in Figure 2. Lure type used in each session (see below) was randomized by angler, and the heavy treatment period only relied on using unnatural colors (firetiger). Only during the before and mid-term assessments also the more natural colour was used. During the before and mid-term evaluation, the approach was using both lure types to estimate the interest per lure type. After the baseline evaluation, only unnatural and deadbait lures were used to assess potential behavioural changes in response to these specific lure types and colours. During the fishing treatment, non-standardized fishing where an angler was free to choose their lures happened in addition, but only by a possible second angler on a boat. This was done to increase the risk to the fish by maximizing encounters with lures.

Table 1. Different standardized lures used.

Bait-Type	Rig	Bait-name	Size	Colour		Company
				Unnatural	Natural	
Deadbait	Drachkovitch	-------------	Around 10 cm	---------	Perch/Ruffe/ Roach/Rudd	------------------
Natural artificial bait	Shad	Zander Pro Shad	7.5 cm; 10 cm; 12 cm	UV Perch	Glitter-perch	Fox International Group Limited, UK
Unnatural artificial bait	Chatterbait + pintail as trailer	WRRR + NDL	S; M; L + 8.9 cm; 10.9 cm; 12.7 cm	H-07 + C-07	H-01 + C-14	Nays, GER

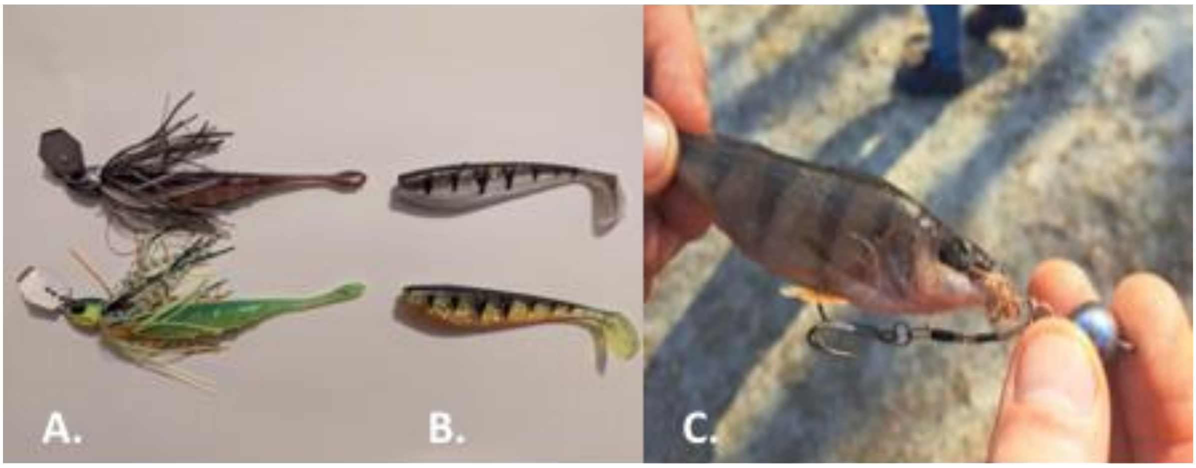

Figure 2. Standardized lures. A. Chatterbait both natural and unnatural colours; B. Shad both natural and unnatural colours; C. Deadbait, perch.

The fishing days where broken down in five time blocks as shown in Table 2. Everyday a dice was rolled for randomisation to determine which timeframe was not to be fished, so four out of five timeframes where fished. This was to control for daytime effects on catch rates.

Table 2. Fished timeframes.

Morning	**Late-morning**	**Afternoon**	**Late-afternoon**	**Evening**
06:00 – 09:00	09:00 – 12:00	12:00 – 15:00	15:00 – 18:00	18:00 – 21:00

To randomize the sampling locations, the lakes were divided into approximately equal-sized areas, as shown in Figure 1 (six in the larger Kleindöllner See and four in the smaller Großer Vätersee). The area to be fished was determined by rolling a dice at random. Each area had to be fished at least once by every individual angler, ensuring efficient and systematic coverage of the entire lake. In each area, every of the three lures was used for a net duration of 30 minutes. Once 1.5 hours of effective fishing time (pausing the stopwatch when handling captured fish) were completed, the next area was randomly selected. This process continued until the end of the working day. Depending on angler availability, one or two anglers fished from a boat on a given day, selecting a new area at random.

Before the start of each fishing session, a standardized protocol, was completed to ensure consistent data collection across all sampling events. The following information was recorded prior to each session: the date, the name of the lake, the initials of the angler, the session number, the area to be fished, the starting and ending time, the type, colour, and size of the lure used, and the retrieve method (jigging or constant retrieval) applied.

Environmental conditions were also documented, including sun visibility on a scale from 0 (not visible) to 3 (fully visible), rainfall intensity on a scale from 0 (dry) to 3 (heavy rain), the percentage of sky covered by clouds, light intensity in lux, wind direction, and wind strength on a scale from 0 (calm) to 3 (strong wind).

In addition, angling activity and fish responses were noted: the number of bites felt, the number of pike and perch followers observed, the number of pike and perch lost after setting a hook, the number of unidentified fish lost, and the number of pike and perch successfully landed. Finally, the total effective fishing time for the session was recorded, excluding time spent on fish handling or other interruptions. All procedures followed a standardized protocol, which is provided in Appendix II.

3.3 Catch processing

Upon a strike, the timer was immediately paused to ensure accurate measurement of effective fishing time. The exact time when the fish was secured in the landing net was recorded. For each captured fish, the following information was documented: the time of capture, the initials of the angler, the area in which the fish was caught, the fishing session, the type, colour, and size of the lure used, and the exact GPS coordinates of the catch location.

In addition, the hooking impact was assessed using a standardized system: hook depth on a scale from 0 (shallow hooking) to 2 (deep hooking), bleeding on a scale from 0 (no bleeding) to 2 (severe bleeding), and hook location on a scale from 1 to 6, where: 1: upper jaw, 2: lower jaw, 3: both upper and lower jaw, 4: gills, 5: stomach, 6: external (along the side of the fish). Then the fish species and total length were recorded (Fig. 3). It was also controlled whether the fish was a recapture by scanning a potential PIT tag and whether it carried an acoustic transmitter, where were previously implanted by the research team in about 230 fish. If the fish (pike and perch) was over 20 cm and did not already contain a PIT tag, one was implanted before release. Additionally, scale samples were taken from each fish over 20 cm for later aging, which was not included in this analysis. After all processing steps were completed and the fish was released and the timer was resumed. All procedures followed a standardized protocol, which is provided in Appendix II.

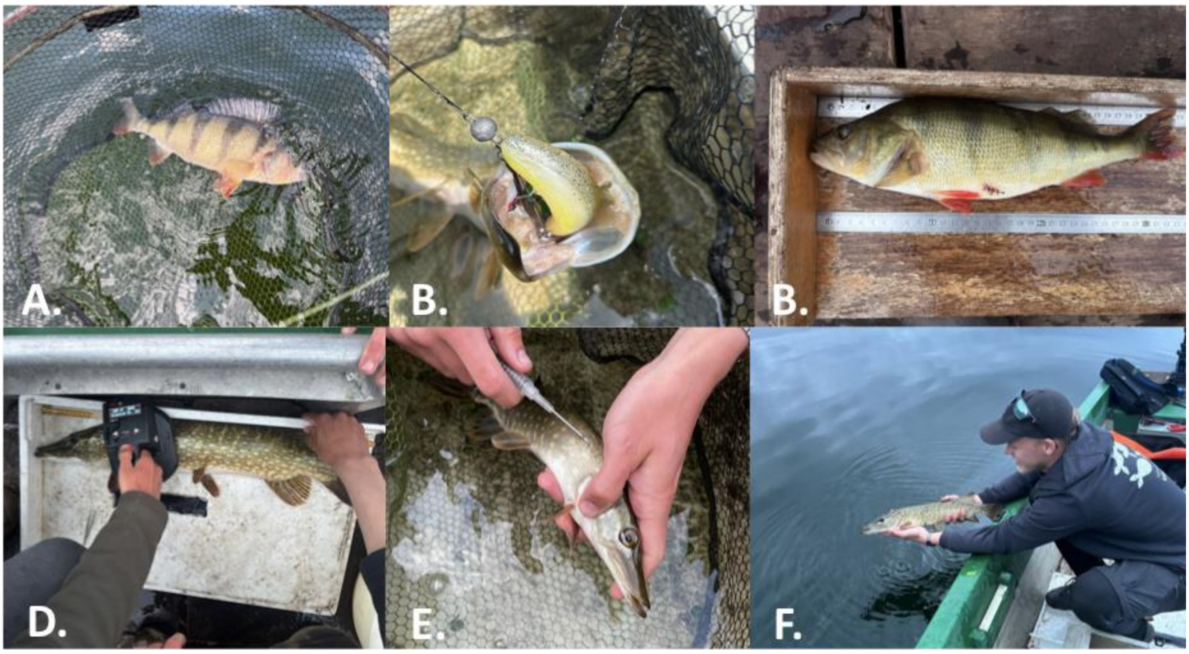

Figure 3. Catch process and fish processing. A. Landing fish and writing down capture time; B. Hook depth, bleeding and hooking location assessment/hook removal; C. Length assessment (individual with transmitter-surgery stitches); D. Controlling whether individual is a recapture; D. Implantation pit tag; F. Pike being released.

3.4 Timespan

Within the BACI (Before-After-Control-Impact) design, it is important to collect data before, during and after the intervention in a treatment (Kleindöllner See) and a control system (Großer Vätersee). To gather before data, three days of experimental fishing were completed in both north and south side of Kleindöllner See and Großer Vätersee to establish a baseline for catch-per-unit-effort (CPUE). Afterwards, for a period of 27 days only the southern part of Kleindöllner See was fished and the northern part as well as Großer Vätersee was left untouched, visible in Table 3. While the intensity varied slightly from day to day depending on availability of experimental anglers, effective angling effort ranged between a minimum of 9 and a maximum of 44 hours per weekday. The mean fishing effort was 20.9 hours per day. This includes the first-and mid-data sampling days. The mid-term evaluation was again conducted in both lakes on the north and south side, investing three experimental angling days in each lake.

Table 3. Timespan of fishing days

	Start evaluation	**Timeframes fished between Start and Mid evaluation**				**Mid evaluation**
Lure types used	Standardized lures both natural and unnatural.	Standardized lure unnatural and unstandardized lures.				Standardized lures both natural and unnatural.
Locations fished	Kleindöllner See and Vätersee both north and south.	Only south Kleindöllner See.				Kleindöllner See and Vätersee both north and south.
Dates fished	14 April 2025; 22 April 2025; 28 April 2025	29 April 2025 – 9 May 2025	12 May 2025 – 16 May 2025	19 May 2025 – 25 May 2025	28 May 2025; 29 May 2025; 3 June 2025; 4 June 2025	30 May 2025; 2 June 2025; 5 June 2025

3.5 Data analysis

The data analysis was done by calculating the average daily CPUE for each part of the lakes (north and south), estimated as the sum of all catches over all anglers and boats over the sum of all effort. Also, for every fishing day, all bites and all caught fish (pike and perch) were added up for each region, and then divided by the effective fishing time. This gave the CPUE values per day for each lake side. The method follows Equation 1 from Van Poorten and Post (2005), visible in figure 4. Only a qualitative assessment was done, without statistical inference methods. The first comparison focused on the difference in CPUE between the south and north sides of Kleindöllner See, during the before and mid-treatment phases and considering the fishing impact in between. The Großer Vätersee was used as a reference to compare trends among CPUE in the north with the south and thereby analyse the potential for dissimilar trends on the north and the south. Having parallel lines in Großer Vätersee on the North and south was a prerequisite for seeing an impact on CPUE in Kleindöllner See when comparing the north and nouth, where only the south experienced a treatment. Otherwise, any temporal changes in Kleindöllner See could have been caused by systematic movements of fish from north to south or otherwise "random" site differences in catch rates.

$$\text{CPUE} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} E_i},$$

Figure 4. Calculation CPUE (Van Poorten and Post, 2005)

All data were calculated for total catches, total bites, catches of pike and catches of perch. Each figure contains data-values: north and south for both lakes, with a trend line estimated by linear regression added for each area. The trend lines show if CPUE went up or down. The difference in the slope of these trend lines (called a "difference in differences") is important for seeing if there was a decline in Kleindöllner See in the south but not in Großer Vätersee (ideally seeing parallel lines in north and south over time). Differences in the starting level (intercepts) show how similar or different the catch rates were between north and south within each lake, but inferences were drawn only from the slopes (trendlines) over time.

4. Results

Total fishing hours invested into the experiment were 874.25 h (net fishing time) and 1264.87 h (gross fishing time). Total fishing hours for Kleindöllner See north (12.5 ha) were 8.58 h/ha (net-time) and 13.34 h/ha (gross-time). Fishing hours for Kleindöllner See south were 53.74 h/ha (net-time) and 76.01 h/ha (gross-time). Fishing hours for Großer Vätersee north summed to 10.16 h/ha (net-time) and 16.58 h/ha (gross-time), and for the south 10.28 h/ha (net-time) and 14.08 h/ha (gross-time). A total of 583 captures of pike and perch were recorded during the research, consisting of 384 pike and 199 perch.

The overall average CPUE across both lakes was 0.69 (net-time) and 0.46 (gross-time) fish/h. For Kleindöllner See, the average CPUE was 0.71 (net-time) and 0.47 (gross-time) fish/h. When broken down by location, Kleindöllner See north showed a higher CPUE with 0.86 (net-time) and 0.55 (gross-time) fish/h, while Kleindöllner See south achieved 0.55 (net-time) and 0.39 (gross-time) fish/h. In Großer Vätersee, the average CPUE was 0.97 (net-time) and 0.61 (gross-time).

As shown in Figure 5A, the net CPUE (catch per unit effort) of all fish caught differed slightly between locations during before data. Kleindöllner See north had a CPUE of 0.87 fish/h, while Kleindöllner See south was slightly lower at 0.67 fish/h. In contrast, Vätersee north showed the highest CPUE at 1.14 fish/h, with Großer Vätersee south closely following at 1.08 fish/h. After the treatment, notable changes occurred. In Kleindöllner See south, CPUE dropped from 0.67/h to 0.43/h, which corresponds to a decrease of approximately 36%. Kleindöllner See north remained nearly stable, with a minor decline from 0.87/h to 0.87/h (specifically from 0.873 to 0.866), representing a change of less than 1%. In Großer Vätersee, both sections showed moderate declines, but importantly the trend in both lake sides was similar. Großer Vätersee north dropped from 1.14/h to 0.85/h, a decrease of around 26%, and Vätersee south declined from 1.08/h to 0.69/h, which is a decrease of approximately 36%. Therefore, while Großer Vätersee showed parallel trends in CPUE, there were dissimilar trends in Kleindöllner See, where only the fished south side showed a drop. This is strong evidence that the fishing treatment had an impact and that there were no north-south movements in fish that could explain catch rates (as inferred from the parallel trends in Großer Vätersee).

As seen in Figure 5B, the before net number of bites per hour was quite similar across most locations: Kleindöllner See north recorded 2.04 bites/h, Kleindöllner See south 1.87 bites/h, and Großer Vätersee south 1.95 bites/h. Großer Vätersee north was slightly higher with 2.39 bites/h. After the fishing treatment, changes in bite rates varied by location. At Kleindöllner See south, the net number of bites dropped from 1.87/h to 1.16/h, a decrease of approximately 38%. In contrast, Kleindöllner See north showed a substantial increase, from 2.04/h to 2.60/h, which equals a 27% rise. In Großer Vätersee, both zones showed a moderate decline, which again showed a parallel trend. Großer Vätersee south went from 1.95/h to 1.75/h with a 10% decrease, while Großer Vätersee North decreased from 2.39/h to 1.94/h with a 19% decrease.

As illustrated in Figure 5C, the net CPUE of pike (number of pike caught per hour) showed differences across locations before and after the angling treatment. In Kleindöllner See, Kleindöllner See north started with a CPUE of 0.79 pike/h, while Kleindöllner See south recorded a slightly lower value of 0.60 pike/h. After the treatment period, Kleindöllner See north remained relatively stable with a small decrease to 0.76 pike/h, a drop of about 5%. However, Kleindöllner See south showed a substantial decline from 0.60 to 0.33 pike/h, representing a 46% decrease. In Großer Vätersee, both areas also experienced decreases but unlike in Kleindöllner See with parallel trends. Vätersee north went from 0.93 to 0.82 pike/h, a reduction of around 12%, while Vätersee south declined more steeply from 0.81 to 0.53 pike/h, a decrease of roughly 34%.

As shown in Figure 5D, the initial CPUE for Kleindöllner See was 0.08 perch/h in the north and 0.07 perch/h in the south. After the treatment, both areas saw an increase in CPUE. Kleindöllner See north rose from 0.08 to 0.11 perch/h, which is an increase of approximately 39%. Kleindöllner See south increased from 0.07 to 0.10 perch/h, a rise of around 53%. In Großer Vätersee, the pattern was different. Großer Vätersee North showed a decline from 0.21 to 0.03 perch/h, a drop of about 86%, while Großer Vätersee south decreased from 0.27 to 0.16 perch/h, a reduction of around 42%. Unlike in pike, there was no evidence for a fisheries-induced impact on catch rates as catch rates rose in Kleindöllner See in both lake sides.

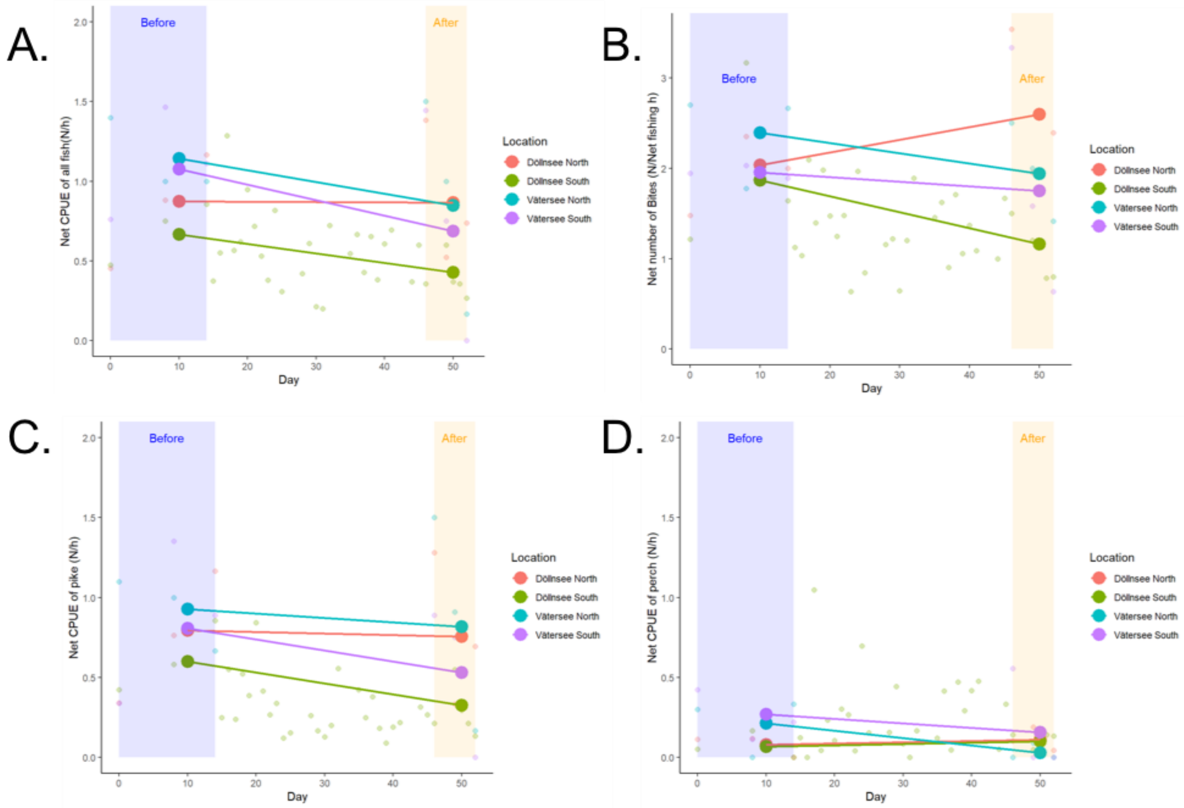

Figure 5. Trend over time. A. Net-CPUE of all fish caught; B. Net-number of bites; C. Net-CPUE of pike caught; D. Net-CPUE of perch caught.

5. Discussion and conclusions

The catch rates of fish in the study lake averaged 0.39 fish/h, which was similar to the pike catch rates reported in a previous whole lake manipulative study in the same study lake by Klefoth et al. (2011) (0.18 pike/h) over a five-month study period. This indicates that the fish abundance in our experimental phase and the resulting catch rates were similar as reported previously.

This study investigated the effects of one month of intensive recreational fishing on the catchability of pike and perch in a small, controlled lake system. Based on previous studies (Beukema 1970; Kuparinen et al. 2010; Arlinghaus et al. 2017b; Lucas et al. 2023; Roser et al. 2024), it was hypothesized that the catchability of these piscivorous fish would decline due to repeated exposure to catch-and-release. Such a decline is thought to result from learning processes, where individual fish associate being caught with a negative experience and subsequently avoid lures (Czapla et al. 2023). The findings for pike strongly supported the study hypothesis. In the heavily fished southern part of Kleindöllner See, the CPUE for pike decreased by 46%, alongside a drop in bite rate of 38%. This contrasts with the stable or even slightly increasing values in the unfished northern section and the otherwise stable (declining) trends in pike CPUE in the control lake Großer Vätersee. The dissimilar trends in Kleindöllner See are fully consistent with fisheries-induced learning that reduced the reactivity of pike to lures. These results might suggest that pike adjusted their behaviour in response to angling pressure, likely through learning to avoid lures, similar to what has been reported before for this species (Beukema 1970; Kuparinen et al. 2010; Klefoth et al. 2011; Arlinghaus et al. 2017b; Lucas et al. 2023; Roser et al. 2024). The conclusion are of course not water proof yet as they were derived from just qualitative trend analysis. More data and a full statistical analysis are needed, which will be provided after the end of June in an associate B.Sc. thesis by Maximilian Roederer. Another B.Sc. thesis by Tammo Steincke will shed light on the behavioural process of lure avoidance in more detail. My conclusions are therefore to be treated as temporary.

For perch, the results were more difficult to interpret, but collectively they showed no evidence for hook avoidance learning. In both Kleindöllner See north and south, CPUE for perch increased after the angling treatmen , and the increase was stronger on the fished southern side. Although Großer Vätersee again showed parallel trends, the CPUE trends in Kleindöllner See rose in the same direction. The findings either indicate differential rates of movement of perch from north to south, which diluted any fisheries-induced impact on the catch rates. It is important to note that perch catches were not consistent throughout the study and that the standardized lures were not tailored for perch fishing, making it harder to draw firm conclusions about the effect of angling pressure on this species. However, based on the preliminary data, there is no evidence for hook avoidance learning in the ongoing experiment in perch.

Overall, the strongest effects of angling pressure were observed in pike in the heavily fished Kleindöllner See south. The stability in unfished zones and the otherwise parallel trends in the control lake Vätersee supports the conclusion that intensive angling can reduce catchability in target species within a short time by up to 40 %. The topic will be further explored in the bachelor thesis of Maximilian Roederer. The conclusion that can be drawn is that maintaining high catch rates in unexploited pike lakes is very hard and that rotating closures or other means to reducing fishing effort at least temporarily maybe necessary for catch rates to stay high (Koeck et al. 2019; Camp et al. 2015)

Literature

Alós, J., Palmer, M., Trías, P., Díaz-Gil, C., & Arlinghaus, R. (2014). Recreational angling intensity correlates with alteration of vulnerability to fishing in a carnivorous coastal fish species. Canadian Journal of Fisheries And Aquatic Sciences, 72(2), 217–225. https://doi.org/10.1139/cjfas-2014-0183

Alós, J., Campos-Candela, A., & Arlinghaus, R. (2018). A modelling approach to evaluate the impact of fish spatial behavioural types on fisheries stock assessment. ICES Journal of Marine Science, 76(2), 489–500. https://doi.org/10.1093/icesjms/fsy172

Arlinghaus, R., Cooke, S. J., Lyman, J., Policansky, D., Schwab, A., Suski, C., Sutton, S. G., & Thorstad, E. B. (2007). Understanding the complexity of catch-and-release in recreational fishing: An integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. Reviews in Fisheries Science, 15(1–2), 75–167. https://doi.org/10.1080/10641260601149432

Arlinghaus, R., Laskowski, K. L., Alós, J., Klefoth, T., Monk, C. T., Nakayama, S., & Schröder, A. (2017a). Passive gear-induced timidity syndrome in wild fish populations and its potential ecological and managerial implications. Fish And Fisheries, 18(2), 360–373. https://doi.org/10.1111/faf.12176

Arlinghaus, R., Alós, J., Pieterek, T., & Klefoth, T. (2017b). Determinants of angling catch of northern pike (Esox lucius) as revealed by a controlled whole-lake catch-and-release angling experiment—The role of abiotic and biotic factors, spatial encounters and lure type. Fisheries Research, 186, 648–657. https://doi.org/10.1016/j.fishres.2016.09.009

Beukema, J. J. (1970). Acquired hook-avoidance in the pike Esox lucius L. fished with artificial and natural baits. Journal of Fish Biology, 2(2), 155–160. https://doi.org/10.1111/j.1095-8649.1970.tb03268.x

Camp, E. V., Van Poorten, B. T., & Walters, C. J. (2015). Evaluating Short Openings as a Management Tool to Maximize Catch-Related Utility in Catch-and-Release Fisheries. North American Journal Of Fisheries Management, 35(6), 1106–1120. https://doi.org/10.1080/02755947.2015.1083495

Czapla, P., Wallerius, M. L., Monk, C. T., Cooke, S. J., & Arlinghaus, R. (2023). Reexamining one-trial learning in common carp (Cyprinus carpio) through private and social cues: No evidence for hook avoidance lasting more than seven months. Fisheries Research, 259, 106573. https://doi.org/10.1016/j.fishres.2022.106573

Klefoth T (2007) Behaviour of pike (Esox lucius L.) in response to angler-induced disturbance in a catch-and-release fishery in Lake Kleiner Kleindöllner See. Humboldt-Universität zu Berlin, Faculty of Agriculture and Horticulture. http://www.adaptfish.rem.sfu.ca/ Thesis_MSc_Klefoth.pdf

Klefoth, T., Kobler, A., & Arlinghaus, R. (2011). Behavioural and fitness consequences of direct and indirect non-lethal disturbances in a catch-and-release northern pike (Esox lucius) fishery. Knowledge and Management Of Aquatic Ecosystems, 403, 11. https://doi.org/10.1051/kmae/2011072

Kobler, A., Klefoth, T., & Arlinghaus, R. (2008). Site fidelity and seasonal changes in activity centre size of female pike Esox lucius in a small lake. Journal Of Fish Biology, 73(3), 584–596. https://doi.org/10.1111/j.1095-8649.2008.01952.x

Koeck, B., Wallerius, M. L., Arlinghaus, R., & Johnsson, J. I. (2019). Behavioural adjustment of fish to temporal variation in fishing pressure affects catchability: an experiment with angled trout. Canadian Journal Of Fisheries And Aquatic Sciences, 77(1), 188–193. https://doi.org/10.1139/cjfas-2019-0064

Kuparinen, A., Klefoth, T., & Arlinghaus, R. (2010). Abiotic and fishing-related correlates of angling catch rates in pike (Esox lucius). Fisheries Research, 105(2), 111–117. https://doi.org/10.1016/j.fishres.2010.03.011

Lewin, W., Arlinghaus, R., & Mehner, T. (2006). Documented and Potential Biological Impacts of Recreational Fishing: Insights for Management and Conservation. Reviews in Fisheries Science, 14(4), 305–367. https://doi.org/10.1080/10641260600886455

Lucas, J., Ros, A., Geist, J., & Brinker, A. (2023). Effects of behavioral strategies on catchability, bait selectivity, and hunting behavior in northern pike (Esox lucius). Canadian Journal Of Fisheries And Aquatic Sciences, 80(12), 1890–1905. https://doi.org/10.1139/cjfas-2023-0004

Nakayama, S., Doering-Arjes, P., Linzmaier, S., Briege, J., Klefoth, T., Pieterek, T., & Arlinghaus, R. (2018). Fine-scale movement ecology of a freshwater top predator, Eurasian perch (Perca fluviatilis), in response to the abiotic environment over the course of a year. Ecology Of Freshwater Fish, 27(3), 798–812. https://doi.org/10.1111/eff.12393

Roser, P., Radinger, J., Feldhege, F., Braun, M., & Arlinghaus, R. (2024). Getting Scarce and Lure Shy: Impacts of Recreational Fishing on Coastal Northern Pike (Esox lucius) Abundance, Size Structure and Vulnerability to Angling. Fisheries Management And Ecology. https://doi.org/10.1111/fme.12769

Schulze, T., Baade, U., Dörner, H., Eckmann, R., Haertel-Borer, S. S., Hölker, F., & Mehner, T. (2006). Response of the residential piscivorous fish community to introduction of a new predator type in a mesotrophic lake. Canadian Journal Of Fisheries And Aquatic Sciences, 63(10), 2202–2212. https://doi.org/10.1139/f06-099

Van Poorten, B. T., & Post, J. R. (2005). Seasonal Fishery Dynamics of a Previously Unexploited Rainbow Trout Population with Contrasts to Established Fisheries. North American Journal of Fisheries Management, 25(1), 329–345. https://doi.org/10.1577/m03-225.1

Wegener, M. G., Schramm, H. L., Neal, J. W., & Gerard, P. D. (2017). Effect of fishing effort on catch rate and catchability of largemouth bass in small impoundments. Fisheries Management And Ecology, 25(1), 66–76. https://doi.org/10.1111/fme.12268

Appendix

Appendix I. Angling session protocol

Angling session protocol

Project:PREDATOR

Date Lake Standard (YES/NO) Boat ID Angler

Angler Initial	Session	Area	Time		Terminal gear					Envrionment						Bites	Follwers		Lost			Land		Effective time	Comments
			Start	End	Type	Rig	Color	Size (cm)	Retrieve Method	Sun (0-3)	Rain (0-3)	Cloud (%)	Light Intensity (lux)	Wind direction	Wind strength (0-3)		Pike	Perch	Pike	Perch	?	Pike	Perch		

Fischutzgebiet (GZ 2243/2-22-2024-29-G)

Appendix II. Fish protocol

Fish protocol | Project:PREDATOR

Date | Lake | Boat ID | Angler

Time	Angler Initial	Area	Session	Standard. (YES=tick)	Terminal gear				Location		Species	Total length (mm)	Body mass (g)	Hooking depth (0-2)	Bleeding (0-2)	Hooking location (1-6)	Recapture (YES/NO)	Transmitter (YES/NO)	PIT tag ID	Comment
					Type	Rig	Color	Size (cm)	Latitude (52.XXXXXX)	Longitude (13.XXXXXX)										

Hooking location: upper jaw (1), lower jaw (2), both upper and lower jaw (3), gills (4), gullet/stomach (5), or external along the side of the fish (6)

Fischutzgebiet (GZ 2243/2-22-2024-29-G)