Impacts of angling experience and J hook size on catch rates, species composition, hooking depth, and bleeding in freshwater recreational pole fishing

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Data Availability Statement

The data supporting the findings of this study are available within the article and its supplementary materials.

Conflict of Interest Disclosure

The authors declare no conflict of interest regarding the publication of this manuscript.

Ethics Approval Statement

All procedures performed in studies involving animals were in accordance with the ethical standards of the institution and the Berlin Fisheries Agency through authorization (FiA – A2).

Title

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Abstract

To enhance the reliability of fishery-dependent data and reduce catch-and-release impacts, understanding the determinants of catch rates and fish injury in recreational fisheries is essential. This study aimed to evaluate the effects of angler experience and hook size on catch outcomes and injury (hooking depth and bleeding) while pole fishing for small-bodied freshwater fish, primarily cyprinids. We conducted experiments using a factorial randomized block design over three years at two sites near Berlin, Germany. Results showed that experienced anglers had significantly higher CPUE than novices, but angler experience did not affect fish size, which was instead influenced by hook size (barbed J hooks 10 to 18) and fishing session. Novice anglers caused more fish bleeding, while hook size had no significant effect on either bleeding or hooking depth. We recommend assessing self-perceived angling skill in catch data analysis and providing training to minimize welfare impacts from novice anglers.

Key words: Angler experience, hook size, fish injury, fish catch, recreational fisheries, CPUE

Introduction

Recreational fishing is defined as fishing of aquatic animals that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on markets (FAO 2012). Angling with rod, reel and line is the most common fishing method in recreational fisheries (Arlinghaus & Cooke, 2009), which is why recreational fishing and (recreational) angling is often used synonymously. At least 220 million people participate in recreational fishing globally in freshwater and saltwater (Arlinghaus et al., 2015). The activity constitutes the dominant use of wild freshwater fish in all industrialized countries (Arlinghaus et al., 2002; Cowx et al., 2010), and also harvests relevant quantities of fish in selected coastal and marine areas (Coleman et al., 2004; Hyder et al., 2018). Its importance is rising rapidly in developing nations (Cowx, 2002; FAO, 2012). Recreational fishers globally remove about 1.3 Mt of the fish from inland waters, which equates to 11.3% of global inland fisheries harvest (Lynch et al., 2024). The actual catch is much larger because about two-thirds of the captures by recreational anglers are released either voluntarily or due to harvest regulations (Cooke & Cowx, 2004). Through demand for angling gear, travel, accommodation etc. recreational fishing can be an important contributor to local and regional economies (Lynch et al., 2024). Other benefits of recreational fisheries related to social, cultural and health dimensions (Arlinghaus et al., 2002; Parkkila et al., 2010; Pita et al., 2018). Therefore, better understanding how recreational fisheries impacts fish stocks and human well being is of relevance (Arlinghaus et al., 2019; Lewin et al., 2006; Post et al., 2002).

Most recreational fisheries in freshwaters occur in water bodies that lack formal stock assessments and are thus considered data poor (Post et al., 2002). As an alternative to fishery-independent assessment, fishery-dependent catch per unit effort (CPUE) can be used to index relative fish abundance across lakes/rivers and over time (Quinn & Deriso, 1999). CPUE is also a determinant of angler satisfaction (Beardmore et al., 2015) and therefore affects fishing effort decisions (Post et al., 2008) and angler well-being (Arlinghaus, 2006; Birdsong et al., 2021). An issue of using angling CPUE as a relative abundance measure is that CPUE might not always be proportional to stock status (Harley et al., 2000; Salthaug & Aanes, 2003). A particular problem is hyperstable catch rates, where catch rates stay high even as fish abundance drops (Dassow et al., 2020; Erisman et al., 2011; Hilborn & Walters, 1992). If hyperstable catch rates exit, CPUE information loses its ability to reliably indicate stock status (Post et al., 2002). Hyperstability among catch rate and abundance has been repeatedly documented for recreational fisheries in both marine and freshwater fish (e.g. Dassow et al., 2020; Erisman et al., 2011; Peterman & Steer, 1981). Reasons can involve schooling behavior of the target species, or the aggregation of the species at a particular habitat that can be easily identified by anglers (Erisman et al., 2011; Post et al., 2002). Another reason explaining hyperstable catch rates can be effort sorting, where skilled anglers characterized by high ability to catch fish substitute low skill anglers as fish abundance drops, keeping average catch rates high (van Poorten et al., 2016; Ward et al., 2013a; Ward et al., 2013b). Evidence for a skill-based effort sorting effect, however, is mixed, with some papers revealing evidence that catchability varies with angler experience (Ward et al., 2013a; Ward et al., 2013b) and others showing that hyperstable catch rates can emerge from species-specific factors alone (Dassow et al., 2020; Mosley et al., 2022). More experimental work that systematically assesses the ability of different anglers to catch fish is necessary as is the development of indices that predict whether an angler is highly skilled in terms of catching fish or not (Seekell, 2011).

While many angler cultures built certain practices around the potential for a skill effect (e.g., fishing competitions, Meinelt et al., 2008), whether an angling skill effect on catch rates exists is poorly documented in the academic literature. What is known is that catch rates are highly unequally distributed among anglers, with a minority of people catching the majority of the fish (Baccante, 1995). But whether this effect is caused by systematic skill effects in terms of finding, attracting, hooking and landing fish (for a full account, Lennox et al., 2017) or is related to other catch-rate determining factors that vary among anglers, e.g., fishing effort investment, is less clear. Seekell (2011) analyzed the distribution of daily catch rates by trout anglers, revealing that the catch rate distribution was not different from distribution expected from random effects alone. However, Seekell (2011) also highlighted that independent measures of angling skill do not exist in most observational data sets collected on angler catch rates, which makes it impossible to estimate a skill effect when studying catch rate distributions alone. Several observational and experimental studies have been completed using various skill or fishing experience indicators that suggest a positive relationship of skill and catchability or catch rate. For example, studies relying on measures of years of fishing experience, frequency of fishing days per year, and target species preferences found these variables to influence catch rates and the species caught (Czarkowski & Kapusta, 2019; Heermann et al., 2013; Ward et al., 2013a; Ward et al., 2013b). Additionally, an experimental study exposing anglers to an unknown research lake revealed a positive relationship of a self-identified measure of angling skill and CPUE, and especially the size of the fish that was captured (Monk & Arlinghaus, 2018). Skill effects on catch outcomes can emerge from the variation in the ability of anglers to find, attract, hook and land fish (Lennox et al., 2017; Monk & Arlinghaus, 2018). Especially in high abundance species such as small-bodied cyprinids fished in parts of Europe during fishing tournaments (Cowx & Broughton, 1986; Kapusta & Czarkowski, 2022; Meinelt et al., 2008), skill effects may also stem from the choice of fish attractants (ground bait; Arlinghaus & Mehner, 2003; Arlinghaus & Niesar, 2005; Niesar et al., 2004), type of bait used (Smith, 2002) and the speed of casting, landing and dehooking, which can all elevates fishing effort per unit time. Another possible impact of angling skill that relates to elevated fishing effort is handling time of processing a fish, which might be greater in less experienced anglers. However, such effects were not found in one experimental study (Clarke et al., 2021).

One key problem for establishing a relationship of skill and catch outcomes is the lack of independent measure of angling skill independent of the actual catch outcomes (Seekell, 2011). In this context, the study of Monk and Arlinghaus (2018) provided a first step forward by developing a simple self-reported skill index that was found predictive of catch rates and sizes of fish in an experimental fishery for Eurasian perch (*Perca fluviatilis*). The present study builds on this work and examines the predictive ability of a self-identified skill index to predict angler catch rates in pole fishing for small-bodied freshwater fish common to European waters.

In recreational fisheries the majority of fish are released after capture either voluntarily or as a result of regulations (e.g., minimum-size limit, Arlinghaus et al., 2007; Cooke & Cowx, 2004). While release rates vary among angling cultures and fisheries, catch-and-release rates are particularly high and may approach 100% for fishing for cyprinid species in Europe (Arlinghaus et al., 2007), which includes fishing for small-bodied cyprinids in fishing competitions and in highly modified water bodies such as canals in the UK (Cowx & Broughton, 1986; Meinelt et al., 2008; North, 2002). In such situations, the amount of injury induced by the anglers becomes an important consideration to maximize survival (Arlinghaus et al., 2007; Brownscombe et al., 2017; Munoeke & Childress, 1994) and more generally to minimize fish welfare impairments (Arlinghaus et al., 2009, 2010). Especially the anatomical hooking location and the depth of hooking have a very large effect on injury and subsequent survival (reviewed in Arlinghaus et al., 2007; Brownscombe et al., 2017; Munoeke & Childress, 1994) and the duration of hook removal by elevating air exposure and possibility to harm the fish skin during handling (Cook et al., 2015; Czarkowski et al., 2023; Gutowsky et al., 2017; Kapusta & Czarkowski, 2022). When a fish is deeply hooked in critical regions such as the gills, oesophagus or stomach, bleeding and fatal injuries are more likely (Arlinghaus et al., 2007, 2008; Bartholomew & Bohnsack, 2005).

Hooking depth, injury and the amount of bleeding depends on multiple factors such as hook type and size (Cooke & Suski, 2005; Grixti et al., 2007; Gutowsky et al., 2017; Kapusta & Czarkowski, 2022), bait/lure size and type (Arlinghaus et al., 2008; Wilde et al., 2003) as well as hook-set behaviour (passive vs. active retrieval, quick hook setting; Bacheler & Buckel, 2004; Cooke et al., 2003; Gutowsky et al., 2017; Larsen et al., 2024; Lennox et al., 2015). Especially the size of the hooks baited with natural bait relative to the gape of the target species, and more generally bait/lure size, can be an important consideration affecting not only the size-selectivity of the capture process (with larger fish captured with larger hooks/baits sizes), but also the depth of hooking and the amount of injury induced (with larger injury with smaller hooks/baits; Alós et al. 2008, a,b; Arlinghaus et al., 2008; Cooke et al., 2005; Czarkowski & Kapusta, 2019; Rapp et al., 2008). In addition, angler skill might determine fish injury, for example by affecting the speed of detecting a bite and the hook set behaviour, which might be larger in novice anglers (Gutowsky et al., 2017). Yet, experimental evidence on how angling experience or skill affects fish injury and bleeding is small in number, low in sample size and overall inconclusive. Novice anglers fishing for trout (*Oncorhynchus mykiss*) injured proportionally more fish than experienced anglers during hook removal (Meka, 2004). By contrast, experienced anglers targeting smallmouth bass (*Micropterus dolomieu*) hooked the fish more deeply in the mouth in comparison to novice anglers, but the handling time was unrelated to angler experience (Dunmall et al., 2001). Similarly, in artificial lure fishing for largemouth bass (*Micropterus salmoides*), no relationship among angler experience and handling time, hooking location and bleeding were found (Clark et al., 2021). Evaluating study results in relation to the impact of skill and terminal gear on injury rates largely depends on the fishing context and target species, the way a lure or natural bait is fished and the gape size of the study species in the context to the hook or bait/lure size. In relation to pole fishing for small-bodied freshwater cyprinids - a very popular form of fishing in Europe (Kapusta & Czarkowska, 2022; Meinelt et al., 2008; North, 2002) - no work exists on the relationship of angling skill and hook size and the fishing outcomes for the angler (catch) and the fish (injury).

The study objective was to assess the impact of angler experience with different hook size on fish catch, hooking depth and bleeding status in coarse/pole fishing of small, bodied freshwater fish. Specific hypotheses tested in the study are as follows:

H_1 Experienced anglers catch more fish per unit time than novice anglers.

H_2 Experienced anglers catch larger fish than novice anglers.

H_3 Experienced anglers cause less injury than novice anglers.

H_4 Large hook sizes catch less fish per unit time than small hook sizes.

H_5 Large hook size catch larger fish.

H_6 Large hook sizes cause less injury than small hook sizes.

Methods

Study area

Pole fishing experiments for small-bodied freshwater fish were conducted in two study areas in three study years (2011, 2020 and 2024). In 2011, fishing experiments took place in a small (25 ha), shallow (maximum depth 7 m), weakly eutrophic natural lake Kleiner Döllnsee located in the biosphere reserve Schorfheide-Chorin about 80 km northeast of Berlin (N 52.99225, E 13.57958). This study lake is a research lake without public access to recreational angling or commercial fishing. Species richness of the fish community in the lake Kleiner Döllnsee is 12 species, with Eurasian perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), and rudd (*Scardinius erythrophthalmus*) being the dominant species (Eckmann, 1995). Angling experiments were completed using pole fishing from a boat over three days during daytime in autumn (September 14 to 16, 2011).

In 2020 and 2024, fishing experiments took place in the urban, channelized section of the river Spree in southeast Berlin, Germany. This river is very slow flowing with a river width of about 150 m and heavy commercial and pleasure boat navigation. The riverbanks are characterized by artificial embankments, and the bottom substrate is composed of fine sediments. There is public recreational fishing in the study section. Fishing experiments were completed from the shore. This downstream section of the river Spree constitutes the bream (*Abramis brama*) region and overall hosts 20 fish species (Wolter, 2001). Dominant species are perch and roach and several other cyprinids (Wolter et al., 2002). In recent years, invasive round goby (*Neogobius melanostomus*) has invaded and reached high abundances (Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt Fischereiamt Berlin, 2024). Experimental angling took place in two fishing areas on opposite banks of the river (N 52.47667, E 13.49725; N 52.47356, E 13.49467). In 2020, three fishing days were completed (September 2 - 4) and in 2024 two (September 25 and 27).

Experimental design

The angling experiments followed a randomized factorial block design that controlled for systematic fishing site effects within each study area (lake Kleiner Döllnsee and urban river Spree) by randomly allocating pairs of angling experience levels (low and high) to randomly selected fishing sites. For each experimental unit (angling experience level) we randomly allocated two different hook sizes (small and large) to fishing sessions. Therefore, angler experience level and hook sizes were the experimental factors that were systematically varied across sites as blocks. In terms of terminology, we differentiate the study area (lake Kleiner Döllnsee multiple sites along the reed belt and urban river Spree with multiple sites distributed over two opposite river sections) and the fishing site (spot) within each area. In each fishing spot we completed multiple fishing sessions with varying hook sizes. During each day, the different experimental angler pairs distributed randomly over multiple fishing sites within the study area. A chosen fishing site was experimentally fished in multiple fishing sessions by pairs of experienced and less experienced anglers in durations between 30 min and 60 min during each sampling day. Distances among fishing sites were at least 10 m; a possible fishing site (block) as well as angler ID, fishing day and session number effect was statistically controlled in further analyses.

On each randomly selected site, a more experienced and less experienced angler was randomly paired so that both experience levels always fished the same site in all three study years in both study areas. Thereby, the differently experienced anglers exploited the same local patch of available fishes. This design allowed a fishing experience effect to be estimated. Angler numbers varied across the three study years, among 6 to 8 (depending on fishing day, half inexperienced, half experienced) in 2011, 12 (six high and six low experience level) in 2020, and 12 (6 low and 6 high experience anglers) in 2024. In case of unequal angler numbers in terms of experience level, a third person was randomly allocated to a fishing pair. In 2011, pole fishing happened from a boat in lake Kleiner Döllnsee, in 2020 and 2024 pole fishing was completed from the banks of the urban river Spree. All fishing was completed with standardized gear (see below).

Each site was fished by the pair of experienced and inexperienced angler in fishing sessions that lasted 30, 45 or 60 min. The actual fishing session duration on site (with the angler pair being fixed) varied among the three experimental years and across fishing days within a given year depending on research objectives. In 2011 (three fishing days) and 2024 (two fishing days) a minimum of two 30 min sessions were fished on each site, where a small (2011: hook size 18, 2024: hook size 14) or a large hook (2011: hook size 12; 2024: hook size 10) was randomly allocated to each 30 min session. In 2020, fishing sessions varied between 45 min (day one), 60 min (day two), and 30 min (day three). Only during the third day was a hook size treatment similar in dimension to the year 2024 added, randomly allocated to each 30 min session (small in 2020 hook size 14, large in 2020 hook size 10). In 2020, during the first two fishing days, a hook size of 14 was fished in all sessions.

On each fishing day, experimental fishing took place between 9 and 5 pm. The actual number of fishing sessions varied depending on time availability and light (2011: total of 14 30 min session over three fishing days; 2020: seven 45 min sessions during first day, six 60 min session during second day, 12 30 min sessions during third day; 2024: total of 16 30 min sessions over two fishing days). During the boat fishing in 2011, after one hour a new site was randomly chosen, fishing with a pole from a boat directed at the lake reed belt. In 2020 a randomly selected pair of experienced and inexperienced anglers was allocated to a fixed fishing site that was fished experimentally for the duration of the entire sampling day. In 2024, after two 30 min sessions were completed, inexperienced anglers chose a new fishing site while the experienced angler previously randomly allocated to a given site did not change the site. This resulted in new compositions of fishing pairs of experienced and inexperienced anglers over the course of the sampling day to control for an angling pair effect. To control for systematic site and angler ID effects, both variables were treated as random effects in subsequent statistical analyses.

Overall, while slight details varied across the three study years, the effects of two experimental factors (angling experience and hook size) were systematically and randomly varied consistently and therefore effects estimable. While the entire data set (hereafter global data set) allowed for an angling experience effect on catch rates and fish injury to be estimated (while controlling for co-variates and random effects such as angler ID, fishing day within a year, fishing site and study year), the combined experience and hook size effect could only be estimated for a reduced data set that was restricted to data from fishing sessions where the two hook size levels were randomly allocated to 30 min sessions (i.e., excluding the first and second fishing day in 2020, hereafter reduced data set).

While qualitatively in all study years large and small hook sizes were fished, the absolute and relative dimensions differed across study years (hook size 18 and 12 in 2011; hook sizes 14 and 10 in 2020 and 2024). To assess the hook size effect, we first ran two hook size levels (small and large) in the reduced data set, which made the data set comparable. However, we also ran year-specific models to assess the robustness of a possible hook size effect, e.g., on depth of hooking, given the different hook sizes used in different study years. These study year-specific analyses did not reveal any systematically different effects and for space reasons are not reported.

Assessment of self-identified angler skill level

In all three experimental years (2011, 2020, 2024), individual angler experience levels were determined using a structured angling skill questionnaire following Monk and Arlinghaus (2018). The approach led to a self-identified angling skill level score. The brief questionnaire was filled out before the angling sessions started and consisted of four items (statements) assessing the self-perceived angling skill relative to other anglers on a rating scale. The question wording in 2020 and 2024 was: “How would you judge your angling skill in comparison to other anglers”. Anglers had to rate four items (recreational angling in general, recreational angling for piscivorous fish, recreational angling for non-piscivorous cyprinid fish and recreational angling with a pole), each on a five-point scale, where 1 = beginner, 2 = less good than average, 3 =

equally good as average, 4 = somewhat better than average, 5 = angling expert following Monk and Arlinghaus (2018).

In 2011, also four items were rated, one item formulated for general angling skill and three items formulated in terms of relative skill of angling for cyprinid fishes and pole fishing. The rating scale in 2011 had six-point levels for two items asking for relative skill assessment using the same question format as in 2020 and 2024, with the scale ranging from 1 = beginner, 2 = less good, 3 = just as good, 4 = rather better, 5 = better 6 = expert. Two additional items were assessed in terms of previous participation in competitive fishing for cyprinids and pole fishing for cyprinids. The question wording was: “Did you ever in your angling career participate in competitive fishing events for small-bodied cyprinids?”. The answer scale was a six-point scale 1 = never, 2= rarely, 3=regularly, 4=frequently, 5= very common, 6= exclusively. The internal reliability of these four items were high in all study years, motivating creation of a summed index over all four items for each angler (Cronbach alpha always larger than 0.8). We used the sum of scores for each of the four items as an index of angling experience (range 4 to 20 for each angler).

To that end, in the 2011 data where a six rather than five-point answer scale was used, we divided each angler’s index by six and multiplied by five, so that in all study years the self-perceived angling skill index ranged from 4 (very low) to 20 (very high) for each angler. This quantitative angling skill index was used in subsequent models to assess statistical support for an impact on catch and injury outcomes. For visualization purposes and to define low and high skilled anglers to be randomly allocated in the factorial block design, each angler was categorized as either having low or high angling experience (two levels) based on a median split of the quantitative skill score, calculated within each year separately.

Fishing gear and experimental fishing operation

The pole fishing experiments targeting small-bodied cyprinid (e.g., roach, bream, rudd, bleak, *Alburnus alburnus*) as well as other small-bodied freshwater species (e.g., round goby, small perch) was performed with the same standardized pole fishing equipment in all study years. In 2011, anglers used a 5 m long pole (Fighter Pro Tele-Stipp from DAM), and in 2020 and 2024 6 m pole rods were used (Quality Island Mutant, DAM Varga CarbonTele Pro). The pole rods were equipped with monofilament main fishing lines (2011: Ø 0.18 mm, 2020 Ø = 0.14 mm, 2022: Ø = 0.20 mm in 2024). Floats of 3-4 g drag were used.

Each angler was free in choosing the lead sinker dimension and configuration, and various lead sinker models were provided for anglers to choose from. In each year the float models were kept identical among anglers. The terminal gear configuration consisted of a small swivel to which a 0.7 m leader with a hook (either small or large) was added (monofilament line dimension Ø = 0.10 mm for hook size 18, only in 2011, Ø = 0.12 mm hook size 14; Ø = 0.14 mm hook size 10). A coast lock swivel snap hook (Profi-Blinker, size 20) was used to connect the main line and leader. Replacement tackle for rig reassembling in case of damage or loss and for systematically changing hook sizes was supplied to each angler. Anglers were free to choose the fishing depth, but each angler was supplied with a plumb lead to identify the water depth at the fishing spot.

In cyprinid angling with poles, it is typical that groundbait made out of several flours is used to attract fish to the fishing site (Mehner et al., 2018; Niesar et al., 2004; Wolos et al., 1992). Groundbait is known to increase catch rates up to a saturation point where catch rates decline, likely due to satiation of the local fish (Arlinghaus & Mehner, 2003; Wolos et al., 1992). Each angler was supplied with the same standardized amount of commercially purchased ground bait.

In 2011 and 2024, each angler received 0.5 kg of dry groundbait per fishing hour and were instructed to use all the groundbait at the completion of the fishing hour. In 2020, each angler received a total of 3 kg groundbait to be used across the entire fishing day. Each angler could use their own judgment on how much water to add to the groundbait and which groundbaiting tactic (loose binding by adding little water that leads to groundbait dispersing in the water column, water-rich binding so that the groundbait sinks to the bottom) to choose during the fishing period to which a given groundbait amount was allocated.

All anglers were also given commercially purchased maggots (*Calliphora sp*.) as typical and commercially available bait types in cyprinid fishing which they could use to complement the groundbait and were also used as mandatory bait. Maggot numbers on the hook were standardized for each session and year but varied across years (1 maggot per hook in 2011, 2 maggots per hook in 2024) and fishing days (in 2020). Importantly, maggot numbers were always standardized within a session, hook size level and experience level, so that an effect on study outcomes can be excluded. All anglers were further provided with a dehooking device, a ruler and a rubber mesh landing net.

The task given to all anglers was to catch as many fish as possible in the allocated time, only relying on the standardized gear and following the rules in terms of groundbait amount and use, rig, hook size and number of maggots on the hook. In each study year, at the beginning of the first sampling day, all anglers present (experienced and inexperienced) were instructed how to build the pole rig and how to generally use the pole rod. All anglers received training when capturing the first fish in dehooking and general fish handling. Inexperienced anglers also received some brief verbal statements (3 minutes duration) that fish catches may be affected by the depth in which the hook is presented, the groundbaiting tactic and the distance to the shore. Experienced anglers were instructed not to provide any other verbal advice during the joint fishing session to novice anglers, but inexperienced anglers might still learn over time by observing the fellow experienced anglers to which they were allocated in pairs on one fishing site.

A possible learning effect on catch rate was estimated during the statistical analysis by considering fishing day as a fixed effect. Anglers had liberty in which depth to fish (which can affect with species bite and the sizes of fish), how to distribute lead sinkers on the line (which can affect the speed by which the maggots sink and the indication of a bite), the groundbait tactic used (which can affect how fish are lured to a spot), and the distance to the shore (up to a maximum of the mainline limited to 6 m from the shore/boat). Additionally, any possible handling time variation among anglers (e.g., while dehooking) or other obstructions of fishing time (e.g., rebuilt rigs during damage, entanglement or gear loss) could affect fishing effort and hence catch rates. We expected a possible skill effect to exert an effect through the combination of these factors.

The data processing and collection was as follows. When an angler caught a fish, the species was identified, and total length recorded to mm level. Before dehooking, hooking depth and presence of bleeding (yes or no) was determined. Hooking depth was assessed in three levels as in previous studies (Arlinghaus et al., 2008; Garner et al., 2016; Rapp et al., 2008,): shallow, when the hook was in the mouth of the fish, deep when the hook was still visible but hooked deep in the mouth or gills and very deep when the hook was swallowed and no longer visible. Very deep happened infrequently, so that the variable was later recorded to shallow vs. deep.

Statistical analysis

Descriptively, the effect of angling experience (two levels, low and high) on species composition of the catch was examined using a chi² contingency test. In the descriptive analysis catch rates were normalized to catch per 30 minutes. To examine impacts of the key independent (predictor) variables angling experience (quantitative score, ranging from 4 to 20) and hook size (categorical variable, small vs. large) on catch outcomes as dependent variables (catch per unit effort, CPUE and size of fish, ln-transformed), we ran generalized linear mixed effects models (package: glmmTMB; Brooks et al. 2017) with either CPUE and size (ln-transformed) as dependent variables, angling experience, hook size, session number and fishing day as fixed effects. Fishing time was considered an offset (as in Monk & Arlinghaus, 2018).

The session number within a day was considered to control for possible local depletion effects or other within day changes in catch outcomes. Similarly fishing day was included to account for variation in catch outcomes among sampling days and possibly to indicate fish learning over time. In all models, study year, angler ID and fishing site were used as random effects to control for these effects. Furthermore, we considered interaction terms among angling experience x fishing day and angling experience x session to examine whether inexperienced anglers learned over time and thereby altered their catch outcomes. Other interaction terms were estimated among fishing experience x hook size to examine whether the hook size effect varied by angling experience level.

We also qualitatively tested interaction effects of hook size x session and hook size x day to see if the hook size effect varied over time, perhaps because of time varying differences in how intensively the fish feed. As hook sizes were not systematically varied in two fishing days in

2020, models with hook size effects included were only run for the restricted data set where the two fishing days were excluded. The global data set thus tested only effects of angler experience, day and session, with the random effects year, fishing spot and angler ID. The fishing experience effect in the global model did not differ from the fishing experience effect in the restricted data set. Therefore, for space reasons only results of the restricted model where two experimental treatments (experience and hook size) were jointly examined are reported in this paper.

Two indicators of injury were examined as categorical dependent variables: hooking depth (two levels, shallow and deep) and bleeding levels (present or absent). The same predictor variables and interactions as explained above were tested using a logistic regression model (package: lme4; Bates et al., 2015). We also examined a hook size effect only with the restricted data set. As before, the global data set examining the fishing experience level only did not differ from the results of the restricted data set where the experience and hook size effects were estimated jointly. Therefore, only results of the restricted data set will be reported. In addition, as hook size treatments in 2011 were different than in 2020/2024, we ran year-specific models as robustness checks on depth of hooking and bleeding. Again, no year-specific effects were revealed, which is why we present the full analysis over all three years included in the modelling. Statistical significance was evaluated at $p < 0.05$.

Results

Descriptive information

Experimental anglers captured 1987 fish, comprising nine different species (Table 1). Roach was the most abundant species in the catch, followed by bleak, round goby and perch (Table 1). Some species such as white bream or sunfish were only captured as single individuals. The species composition of the catch by experienced and novice anglers did not differ significantly (Table 1). Experimental anglers fished a total of 423 sessions varying among 30 and 60 min (96 in 2011, 145 in 2020 and 182 in 2024). Overall, the mean catch per unit effort (CPUE) normalized per 30 min fishing session duration was about 4 fish per 30 min (Table 2). Experienced anglers caught nearly twice as many fish per unit time (average CPUE of 5.7 fish per 30 min) compared to novices (2.9 fish per 30 min) (Table 2), but variation in CPUE was greater in experienced anglers than in novices (Fig. 1, Table 2).

In terms of fish size, the overall mean length of fish captured was 160 mm (Table 2). Experienced anglers caught on average, slightly larger fish (162 mm) compared to novices (156 mm), but differences were minimal (Fig. 2). The size of the fish ranged from a minimum of 55 mm for a round goby to a maximum of 472 mm for a bream.

Table 1. Species composition of fish caught across multiple years by experimental pole fishing anglers, categorized by overall counts and for experienced and novice anglers. Statistics represent the results of a χ^2- test assessing the association between the species composition in the catch and angler experience. Asterisks (*) denote statistical significance levels, with * indicating p < 0.05, ** indicating p < 0.01, and *** indicating p < 0.001.

Species	Overall	Experienced	Novice	Statistics
Bleak (*Alburnus alburnus*)	10.7% (n= 212)	10% (n=149)	11% (n=63)	χ^2= 8.8168
Bream (*Abramis brama*)	8.1 % (n= 161)	8% (n=112)	9% (n=49)	*df = 8*
Round goby (*Neogobius melanostomus*)	9.5% (n= 188)	9% (n=135)	10% (53)	*p = 0.358*
Hybrid (cyprinid)	0.4% (n= 8)	0.7% (n=7)	0.4% (n=1)	
Perch (*Perca fluviatilis*)	2.2 % (n= 44)	3% (n=37)	1.2% (n=7)	
Roach (*Rutilus rutilus*)	66.6% (n= 1316)	66% (n=949)	66% (n=367)	
Rudd (*Scardinius erythrophthalmus*)	2.8% (n= 55)	3% (n=42)	2% (n=13)	
Sunfish (*Lepomis gibbosus*)	0.1% (n= 1)	0% (n= 0)	0.4% (n=1)	
White bream (*Blicca bjoerkna*)	0.1% (n= 2)	0.3% (n=2)	0% (n= 0)	
Total	100% (n=1987)	100% (n= 1433)	100% (n= 554)	

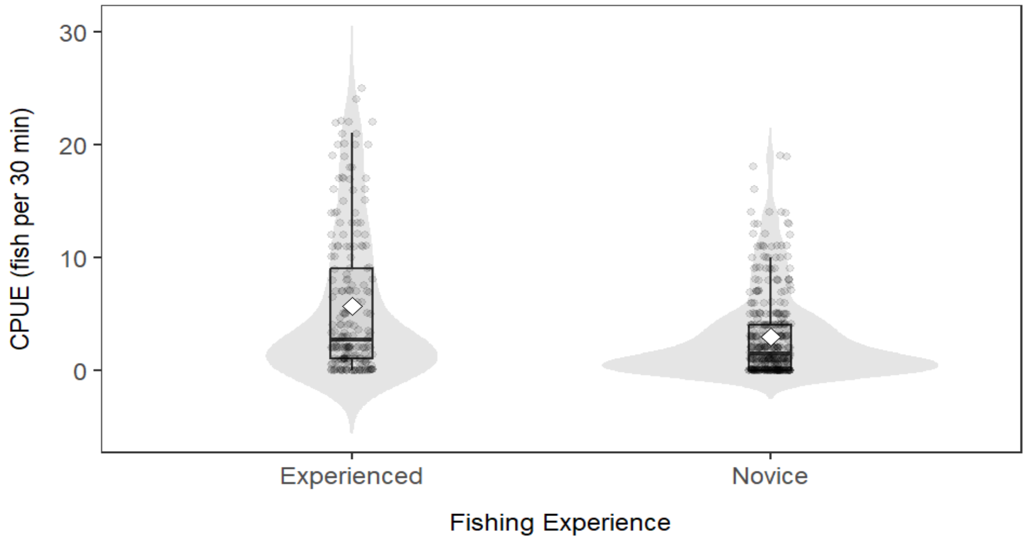

Figure 1. *Violin plots illustrating the distribution of catch per unit effort (CPUE – fish per 30 min) for all fish caught across multiple years, comparing experienced and novice anglers. The grey areas show the density of CPUE observations, with wider sections representing higher frequencies. Boxplots embedded within the violins display the median CPUE (central horizontal line), interquartile range (IQR, 25th–75th percentiles), and whiskers extending to 1.5 times the IQR. Individual CPUE observations are represented by jittered black dots, while white diamonds indicate the mean CPUE for each angling experience category.*

Table 2. *Descriptive statistics of catch per unit effort (CPUE - fish per 30 min) and fish length (mm). The statistics provide the mean values along with standard deviations for all three study years combined and separated into experienced and novice anglers.*

	Overall	Experienced	Novice
CPUE (fish 30 min)			
Mean	3.92 ± 5 (n= 423)	5.7 ± 6.4 (n= 142)	2.9 ± 3.7 (n= 281)
Median	2	2.67	1.5
Range	25	25	19
Length of fish (mm)			
Mean	160.5 ± 41 (n= 1987)	162 ± 42.4 (n= 1433)	156.3 ± 36.9 (n= 554)
Median	158	160	155
Range	422	422	266

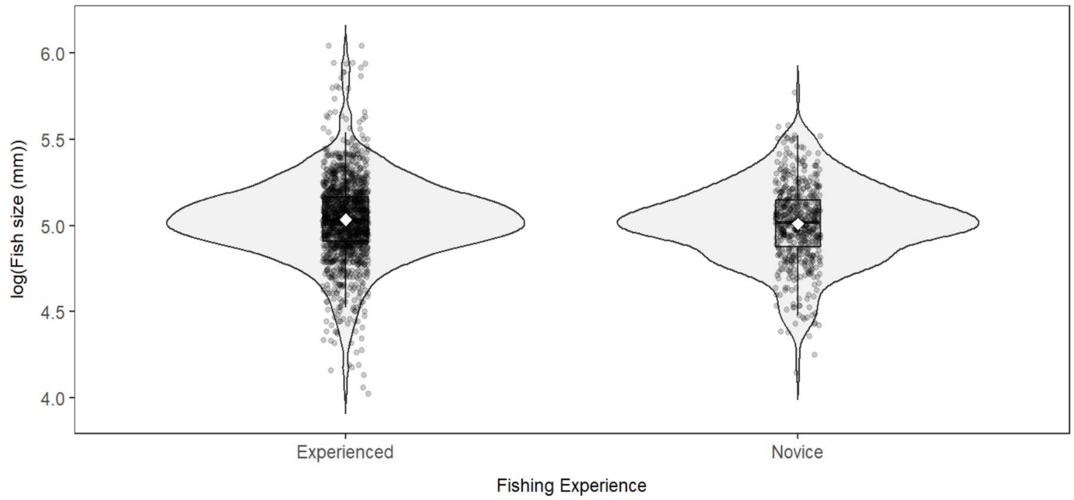

Figure 2. *Violin plots showing the distribution of log-transformed fish lengths for all fish species across different fishing experience categories. Grey areas indicate the density of fish length observations, with wider sections representing higher frequency. Boxplots within the violin plots display the median log-transformed fish length (central horizontal line), the interquartile range (IQR, 25th–75th percentiles), and whiskers extending to 1.5 times the IQR. Jittered black dots represent individual fish length observations, and white diamonds denote the mean log-transformed fish length for each fishing experience category.*

Impact of experience and hook size on catch per unit effort (CPUE)

Using generalized linear mixed models (GLMM), we found that angler experience (measured in a scale from 4 to 20) was significantly ($p < 0.001$) and positively related to CPUE in pole fishing (Fig. 1, Tab. 3). The positive estimate (0.109) showed that each unit increase in self-perceived angler experience increased the number of fish caught by approximately 0.1 fish per session. No other significant variables explaining CPUE were found. Specifically, there was no significant effect of hook size, session or date on angler CPUE (Table 3). The fishing experience effect was consistent across sessions and sampling days, indicated by the lack of significant interactions.

Table 3. *Output of the generalized linear mixed model (GLMM) with a negative binomial error distribution, assessing the effect of various predictors on the number of fish caught per session. Fixed effects included fishing experience, hook size, session, and fishing day (day), along with their interactions. Random effects accounted for variability across fishing year, angler, and fishing site. Model output parameters are the estimated coefficients for each predictor, standard error, z-value, and p-value. Asterisks (*) next to p-values denote levels of statistical significance, with * indicating p < 0.05, ** indicating p < 0.01, and *** indicating p < 0.001.*

	Estimates	Std. error	t-value	Pr(>|z|)
Fishing experience	0.109	0.023	4.665	<0.001***
Hook size small	-0.163	0.22	-0.74	0.459
Session	0.014	0.034	0.42	0.674
Day	0.116	0.133	0.877	0.381
Fishing experience x Hook size	0.011	0.012	0.933	0.351
Fishing experience x Session	-0.002	0.002	-0.939	0.348
Fishing experience x Day	0.005	0.01	0.474	0.635
Hook size x Day	-0.004	0.079	-0.052	0.959
Hook size x Session	0.03	0.021	1.389	0.165

Impact of experience and hook size on fish length in the catch

The size of fish captured by anglers did not differ along fishing experience levels, and anglers with different experience caught similar fish over sessions and fishing days (no significant interaction terms, Table 4). By contrast, hook size and session interacted to affect the fish length (Table 4, Fig. 3). There was a very small and practically largely irrelevant trend for smaller hooks captured somewhat larger fish (as suggested by the significant main effect coefficient for small hooks in Table 4), but this difference vanished over the various sessions (negative interaction term of hook size and session, Table 4, Fig. 3). The fishing experience effect was consistent across sessions and sampling days, indicated by the lack of significant interactions.

Table 4. *Output of the linear mixed-effects model (LMM) with a gaussian error distribution, assessing the effect of various predictors on fish length (log-transformed)**.** Fixed effects included fishing experience, hook size, session, and fishing day (day), along with their interactions. Random effects accounted for variability across fishing year, angler, and fishing spot. Model output parameters are the estimated coefficients for each predictor, standard error, degrees of freedom (df), t-value, and p-value. Asterisks (*) next to p-values denote levels of statistical significance, with * indicating p < 0.05, ** indicating p < 0.01, and *** indicating p < 0.001.*

	Estimate	Std. Error	df	t value	Pr(>|t|)
Fishing experience	0.001	0.004	154	0.176	0.861
Hook size small	0.088	0.041	1950	2.157	0.031*
Session	0.026	0.006	104	4.004	0.0001***
Day	-0.001	0.023	657	-0.05	0.961
Fishing experience x Hook size small	-0.003	0.002	1952	-1.469	0.142
Fishing experience x Session	-0.0005	0.001	67	-1.177	0.243
Fishing experience x Day	0.002	0.002	553	1.163	0.245
Hook size small x Day	-0.017	0.014	1953	-1.217	0.224
Hook size small x Session	-0.011	0.0038	1958	-2.948	0.003**

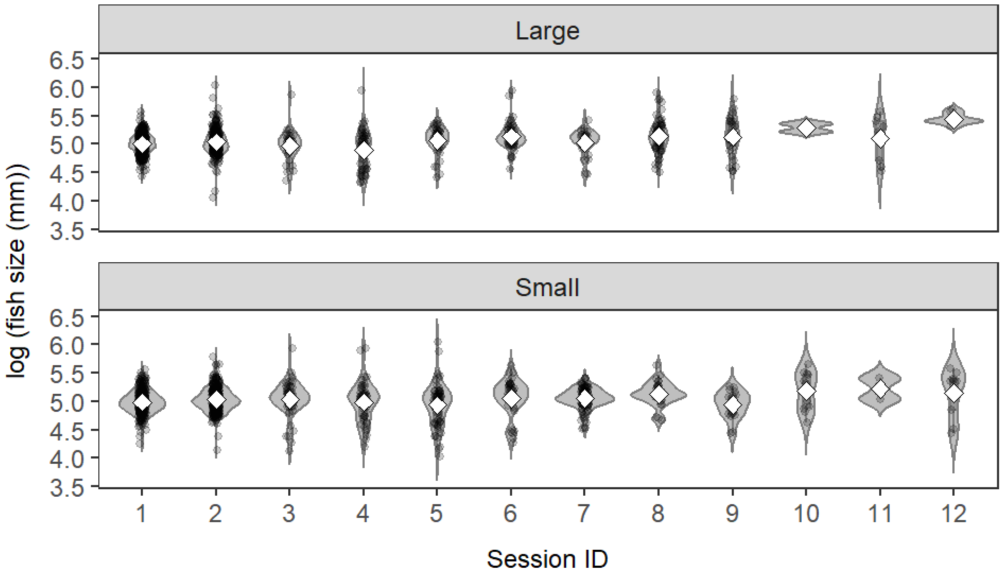

Figure 3. *Violin plots showing the distribution of log-transformed fish lengths across different sessions for each hook size category. Each violin plot represents the distribution of log-transformed fish sizes grouped by fishing session and faceted by hook size. Gray areas indicate the density of fish length observations, with wider sections representing a higher frequency. Boxplots within the violin plots display the median log-transformed fish length (central horizontal line), the interquartile range (IQR, 25th–75th percentiles), and whiskers extending to 1.5 times the IQR. Jittered black dots represent individual fish length observations, and white diamonds denote the mean log-transformed fish length for each session within each hook size category.*

Impact of angler experience and hook size on hooking depth

Interpreting the logistic regression model, the depth of hooking induced by anglers of varying experience did not vary significantly with angler experience as main effect (Fig. 4, Tab. 5). Experienced and novice anglers induced roughly 20 % (n= 397 out of 1987 fish) deep hooking (Fig. 4). Also, hooking depth was independent of hook size (Tab. 5). However, there was a significant fishing experience and session interaction (Tab. 5), suggesting that the degree of hooking induced across angler experience varied among sessions (Fig. 5). The proportion of deep-hooked fish among experienced anglers ranged from 13% to 36% across sessions (Fig. 5). Novice anglers showed more variation in deep hooking, with proportions ranging from 14% to 50% (Fig. 5).

While there was a non-significant trend for increasing fishing experience reducing the degree of deep hooking (negative sign of the experience coefficient in Table 5), the differences among experience levels in hooking depth decreased over session (negative interaction term experience with session, Table 5). There was no indication that hooking depth varied overfishing days.

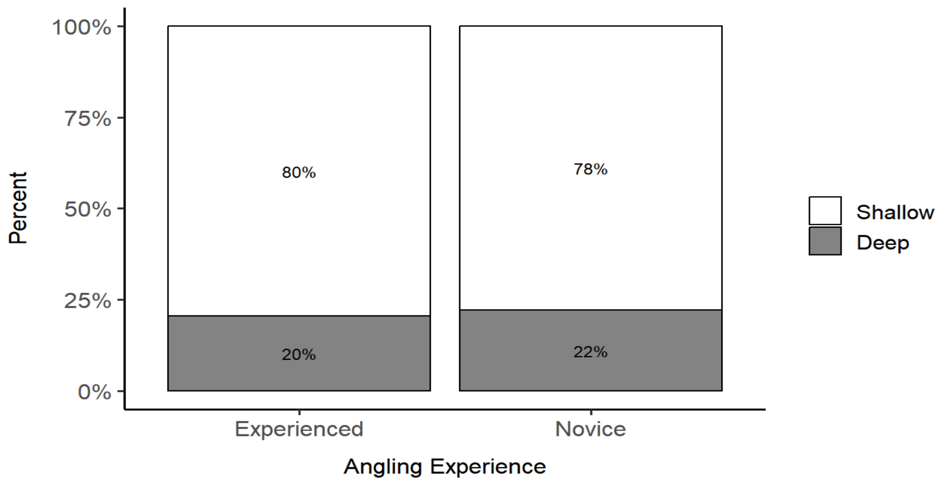

Figure 4. *Stacked bar plots showing the hooking depths over three study years for experienced and novice anglers. The left and right bars represent experienced and novice anglers, respectively. Segments indicate the percentage of shallow (white areas) versus deep hooking (grey areas). Each bar represents an angling experience, with segments indicating the percentage of shallow versus deep hooking depths for each experience level.*

Figure 5. *Stacked bar plots showing the hooking depths across sessions over multiple years separated by fishing experience. Each bar represents a fishing session, and the height of the bar segments indicates the percentage of shallow (white areas) versus deep hooking (grey areas) recorded within that session.*

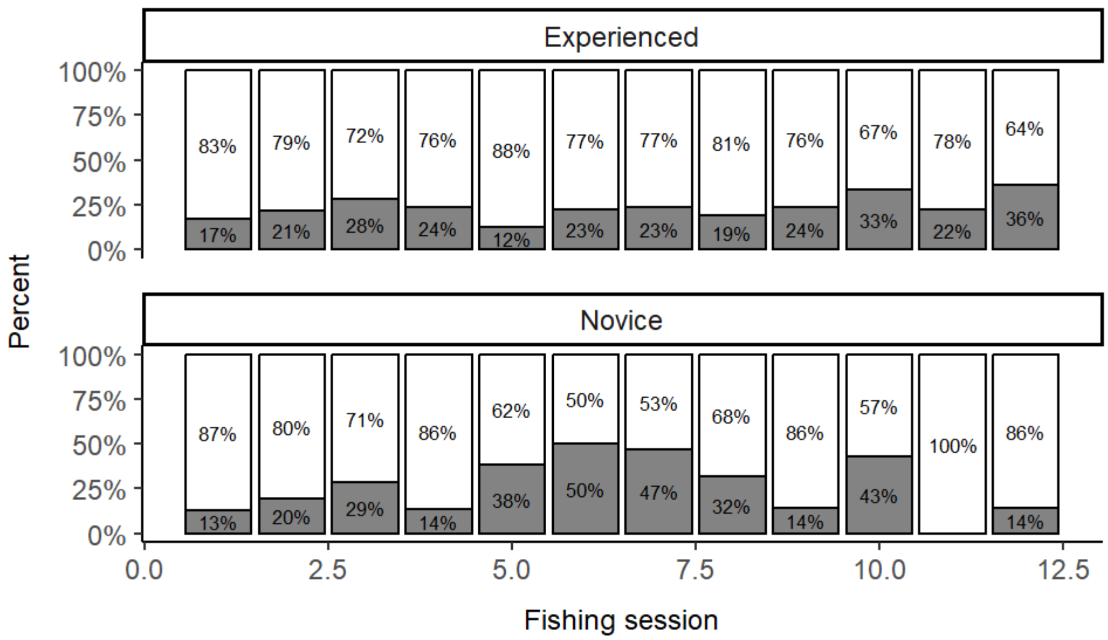

Table 5. *Output of the generalized linear mixed model (GLMM) with a negative binomial error distribution assessing the effect of various predictors on hooking depth. The dependent variable was coded as 1 for deep hooking and 0 for shallow hooking. A negative coefficient means that as the number of sessions increased, the likelihood of deep hooking decreased. Fixed effects included fishing experience, hook size, session, and fishing day (date), along with their interactions. Random effects accounted for variability across fishing year, angler, and fishing spot. Model output parameters include the estimated coefficients for each predictor, standard error, z-value, and p-value. Asterisks (*) next to p-values denote levels of statistical significance, with * indicating $p < 0.05$, ** indicating $p < 0.01$, and *** indicating $p < 0.001$.*

	Estimate	Std. Error	z-value	Pr(>|z|)
Date	-0.324	0.268	-1.209	0.227
Fishing experience	-0.028	0.046	-0.626	0.531
Session	0.165	0.073	2.246	0.025*
Hook size small	0.131	0.462	0.284	0.777
Day x Fishing experience	0.026	0.02	1.269	0.205
Fishing experience x Session	-0.01	0.005	-1.966	0.049*
Fishing experience x Hook size small	0.011	0.024	0.44	0.66
Day x Hook size small	-0.183	0.161	-1.136	0.256
Session x Hook size small	-0.008	0.043	-0.186	0.856

Impact of angling experience and hook size on bleeding status

As part of the fish welfare assessment, we descriptively compared the bleeding status of caught fish between experienced and novice anglers. Novice anglers caused almost three times the amount of bleeding, with 20% (n= 111 out of 554 fish) of their catch showing signs of bleeding, compared to only 7% (n= 100 out of 1433 fish) with bleeding for experienced anglers (Fig. 6). Logistic regressions showed that the probability of bleeding was significantly greater in less experienced anglers (Table 6). By contrast, hook size did not significantly affect bleeding status, and there were no significant interactions among angler experience and hook size (Table 6).

Table 6. *Output of the generalized linear mixed model (GLMM) with a negative binomial error distribution assessing the effect of various predictors on the likelihood of bleeding. Fixed effects included fishing experience, hook size, fishing session, and fishing day (Date), along with their interactions. Random effects account for variability across fishing year, individual angler, and fishing spot. Model output parameters include the estimated coefficients for each predictor, standard error, z-value, and p-value. Asterisks (*) next to p-values denote levels of statistical significance, with * indicating p < 0.05, ** indicating p < 0.01, and *** indicating p < 0.001.*

	Estimate	Std. Error	z-value	Pr(>|z|)
Day	-0.608	0.357	-1.704	0.088
Fishing experience	-0.192	0.072	-2.676	0.007**
Session	0.019	0.09	0.214	0.831
Hook size small	-0.655	0.569	-1.151	0.250
Day x Fishing experience	0.041	0.029	1.408	0.159
Fishing experience x Session	0.001	0.007	0.08	0.936
Fishing experience x Hook size small	0.002	0.032	0.066	0.947
Day x Hook size small	0.203	0.21	0.969	0.333
Session x Hook size small	-0.005	0.059	-0.093	0.926

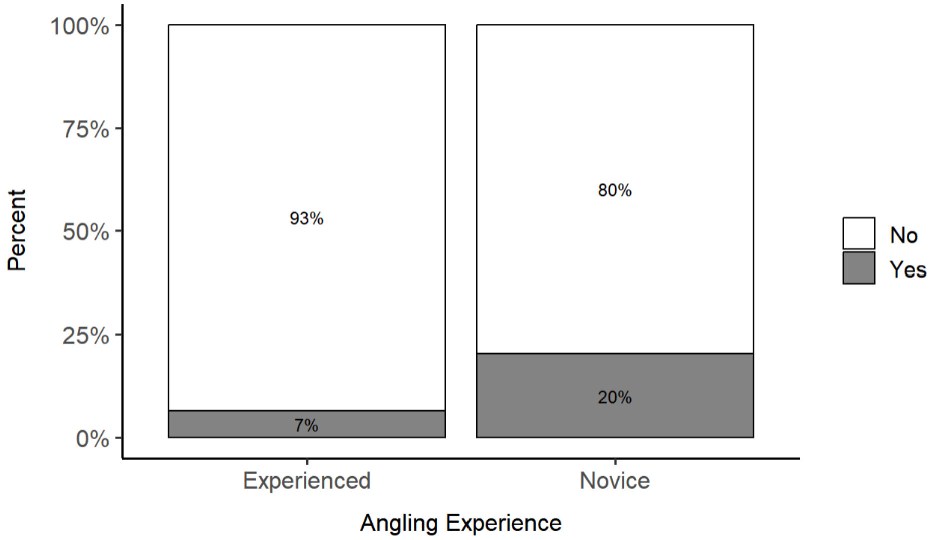

Figure 6. *Stacked bar plots showing the bleeding status of the caught fish over multiple years for experienced and novice anglers. The left and right bars represent experienced and novice anglers, respectively. Segments indicate the percentage of bleeding status of the fish captured by anglers.*

Discussion

In this study, we aimed to evaluate how angler experience and hook size influence catch outcomes and fish welfare, measured by bleeding status and hooking depth, in freshwater pole fishing for small-bodied fish. To address these questions, we proposed six hypotheses: (H_1) experienced anglers catch more fish per unit time than novice anglers; (H_2) experienced anglers catch larger fish; (H_3) experienced anglers cause less injury to fish; (H_4) large hook sizes reduce catch rates; (H_5) large hook sizes result in larger fish; and (H_6) large hook sizes cause less injury than smaller hooks. These hypotheses were tested by collecting data on catch per unit effort (CPUE), fish size, bleeding status, and hooking depth across two angler experience levels and varying hook sizes over multiple years.

Overall, our findings provided strong support for two of the six hypotheses, with partial support for three and no support for one. Specifically, we found strong evidence that experienced anglers caught significantly more fish per unit time than novice anglers, with nearly double the catch rate (H_1). As a side finding, there was no evidence of short-term learning among novice anglers regarding their catch rates, as they did not improve within the study period. Contrary to expectations, angler experience did not affect the size of fish caught (H_2), suggesting that skill enhances the quantity but not the size of the catch. However, fish size was significantly influenced by both hook size and fishing session. Smaller hooks captured larger fish, and continuous fishing sessions resulted in progressively larger fish. Moreover, there was an interaction effect between hook size and fishing session, indicating that smaller hooks were associated with the capture of larger fish particularly in later sessions.

Regarding injury and fish welfare, novice anglers caused more bleeding in fish than experienced anglers (H_3), although this effect diminished over time, indicating rapid improvement in handling techniques. There was an inconsistent and likely spurious effect of angler experience on hooking depth, which appeared to vary with fishing sessions but did not show a consistent trend. As for hook size, our results showed no significant impact on overall catch rates (H_4). Although smaller hooks showed a marginal tendency to capture larger fish later in the fishing sessions (H_5), this effect was not biologically meaningful, as the average sizes were quite similar across hook sizes. Neither bleeding nor hooking depth was significantly influenced by hook size. A weak interaction was observed between hook size and fishing date on bleeding, with larger hooks causing slightly more bleeding initially, but this effect diminished over time and was not significant. Thus, hook size had no consistent effect on injury (H_6).

Catch rates in a specific location in fisheries at a given time are directly related to the population-level catchability coefficient, which is a dynamic variable in fisheries science and stock assessment. This study demonstrated that anglers who rated their skills highly caught more than double the number of fish per unit time compared to novice anglers. A similar observation was made in perch fishing by Monk and Arlinghaus (2018). Previous research has noted variations in anglers' impacts on fish stocks (Baccante, 1995; Jones et al., 1995), and it's well understood that angler experience varies across the population (Bannerot & Austin, 1983; Fisher, 1997; Ward et al., 2013). Therefore, the same sites were used in this study.

Furthermore, catching fish is influenced by encounter rates, the condition of individual fish for example hunger levels, and gear properties such as lure size (Lennox et al., 2017). In this study, gear properties were sufficiently standardized, allowing for their exclusion as a variable.

Encounter rates were also largely controlled by pairing high self-perceived anglers with novices at the same site. However, angler decisions regarding ground baiting, fishing depth, timing of catch detection, and dehooking could still have resulted in different encounter rates between skilled and novice anglers. Monk and Arlinghaus (2018) noted that despite similar encounter rates in perch fishing, skilled anglers caught more fish due to their ability to effectively play the lure and identify the right conditions. However, this finding contradicts the results of Czarkowski and Kapusta (2019), who reported that angling experience did not have a statistically significant effect on catch rates. Hilary et al. (2013) also found no evidence of a relationship between catchability adjusted for angler skill level.

The linear mixed-effects model showed negative results for a tested potential interaction between the independent variable of angling experience and the average length of catched fish (see Fig. 3, Table 4). The violin plots for the distribution of log-transformed fish lengths of all fish species show for both angler types an only slightly differently shaped IQR with the highest frequency and a similar mean at around 50 mm, respectively. Therefore, although experienced anglers caught both, the largest and smallest fish - only whiskers for experienced anglers reached length beneath 60mm and below 40mm -, the overall variability in fish size between the two groups remained comparable. With the majority of fish caught being of average sizes in both groups, no evidence for any implication of the factor experience on the average length of catch per session and angler was found. This is why (H_2) must be rejected here, whereas experienced anglers catch larger fish than novice anglers.

These results contradict findings of former studies (e.g. Meka, 2004; Monk & Arlinghaus, 2018; Heermann et al., 2013). However, they can be validly explained by the terminal gear used and the location fished, which were standardized for all anglers. It is known that bait and hook size have the main impact on the size of fish catched (Weltersbach et. al, 2019). As for the present study, all anglers were prescribed to use identical bait size during all sessions and experienced anglers could not make use of their superior knowledge about adventurous bait dosage. Also, they could not look for favorable angling spots, known to be occupied by larger fish, as all anglers were bound to the same, too. Therefore, no size effect could be expected.

The findings of this study support hypothesis (H_3), which posits that experienced anglers cause less injury to fish, particularly bleeding, compared to novice anglers. This can likely be attributed to the greater skill of experienced anglers in dehooking and fish handling, which minimizes the application of excessive force and reduces the time the fish spends being handled. Novice anglers, on the other hand, may have used more force or mishandled the fish during dehooking, leading to increased injury rates.

However, the specific mechanisms contributing to the observed injury patterns remain speculative in this study, as direct measurements of force were not taken. One possible explanation for the higher injury rates among novice anglers is that they may have struggled with dehooking, applying more force when removing deeply embedded hooks, as has been suggested in previous studies (Cooke & Suski, 2005). In line with this, Dunmal et al. (2001) found that inexperienced anglers often contribute to higher post-release mortality due to improper handling. Similarly, Clark et al. (2021) highlighted the importance of angler skill in reducing stress and injury, supporting the notion that novice anglers’ lack of proficiency can increase the likelihood of fish injury. The results of this study are consistent with these findings, reinforcing the importance of angler experience in minimizing harm to fish.

However, it is important to note that this study used standardized hook types across all participants, eliminating hook variation as a contributing factor to the novice effect. The rapid improvement in novice anglers over time could be attributed to social learning, as novice anglers likely observed and imitated the techniques of more experienced anglers. This aligns with the findings of Meka (2004), who noted that novice anglers quickly improve their handling techniques, reducing injury rates with practice. The differences in fish injury observed in this study are likely due to a combination of novice anglers' lack of proficiency in handling and dehooking, coupled with the quick learning curve they exhibit over time. Further research could explore the exact mechanisms of force application during dehooking, as well as more detailed behavioral observations of novice anglers.

Our results indicate that hook size had no impact on catch rate, which contrasts with hypothesis (H_4) which predicted that large hook sizes would catch fewer fish per unit time than small hook sizes. Thus, opposes previous studies of (Alós et al., 2008a, 2008b; Cerdà et al., 2010) that the use of small hooks resulted in a significant increase in catch per unit effort (CPUE) and larger hooks tended to catch larger fish compared to smaller hooks. This study showed that hook size had a limited impact on the size of fish caught, smaller hooks had a marginal effect on capturing larger fish, particularly in later sessions that goes opposite to hypothesis (H_5), the difference was not biologically relevant, as the mean sizes were quite similar.

One possible explanation for our findings is that the differences in hook size used in this study were too small to have a meaningful impact on catch rate or fish size. We used hook sizes 10, 14 and 18 that differed just slightly. Previous research (Cooke et al., 2005) has shown that hook size can have a significant effect on fish size and catch rate, but the differences in hook size used were substantial (1/0, 2, 6, 10, and 14). (Alós et al., 2008a, 2008b) found that larger hooks caught larger fish, with size of hooks (4, 6, 8, 10 and 14) which also seems broader than current study. Therefore, it is possible that these small differences in hook size were not enough to produce a noticeable effect on catch per unit effort (CPUE) and fish lengths. It can be even dependent on species-specific responses (Cerdà et al., 2010).

Additionally, the standardization of bait size across different hook sizes likely contributed to this lack of variation, as the bait size remained consistent and did not pose a constraint for the fish targeted in fishery in our study. We used the same number and type of maggots as bait on all hooks for each session. This means that the hooked bait size was identical regardless of hook size. As a result, the fish may have been equally likely to bite on any of the hooks. so, bait size can sometimes show an influential impact on catch rates and size.

No practically relevant impact of hook size on injury was found in our present study. This rejects hypothesis (H_6) - Large hook sizes cause less injury than small hook sizes. Specifically, no impact was observed on the depth of hooking, and the limited effect on bleeding was negligible, indicating it holds no practical relevance. This finding suggests that factors other than hook sizes may play a more critical role in influencing injury induced by angling. This is an intriguing finding that revealed mixed results when compared to the past studies. While some studies examining the effect of J-hook size on hooking depth in various angling settings and targeted species align with our results (Alós et al., 2008a; Ateşşahin & Dürrani, 2023; Cooke et al., 2005), other studies found that hook size had a significant impact on the hooking depth (Alós et al., 2008b; Grixti et al., 2007; Mapleston et al., 2008; Rapp et al., 2008). Notably, in the studies by Alós et al. (2008b) and Mapleston et al. (2008), not all studied species showed an impact from hooking size, suggesting this effect can be species specific. Furthermore, Grixti et al. (2007) employed much larger hooks (sizes 8, 4, and 1/0) than those used in our study and covered the entire hook with podworm bait. Regarding the influence of hooking size on bleeding, our findings are more consistent with the literature (Ateşşahin & Dürrani, 2023; Cooke et al., 2005; Rapp et al., 2008). An exception is the study by Mapleston et al. (2008), which found that larger hooks consistently caused more bleeding across all species studied; however, significant differences were noted only in saddletail snapper (*Lutjanus malabaricus*), with no significant differences in the other five species, again highlighting species specificity.

We propose two hypothetical explanations for our controversial findings: 1. The standardization of bait type and amount may have minimized the effect of the hook sizes on injury; and 2. The hooking-related injury might be species-specific. In our present study, we standardized the bait type and amount (either 1 or 2 maggots), which, along with the hook, forms a whole unit which the fish will swallow. The size of the whole unit might determine the hooking depth more than the hook size alone. Furthermore, some previous studies did not find significant correlation across all studied fish species (Alós et al., 2008b; Mapleston et al., 2008), suggesting that the effect of hook size on hooking depth might be species specific. This might be explained by different species exhibit varying gape sizes, feeding styles and strategies (Ebeling & Cailliet, 1974; Ferry-Graham & Lauder, 2001; Mihalitsis & Bellwood, 2017), hence swallow their bait/hook combination at different depths. Thus, these factors contribute to the complexity of understanding the relationship between hook size and injury. By rejecting the working hypothesis - larger hook sizes cause less injury than smaller ones - we underscore the complexity of the factors influencing injury in angling. This finding not only challenges existing assumptions but also highlights the need for further investigation, to confirm whether there is a species-specific hook size effect on injury with standardized bait type and amount, hence providing a more comprehensive understanding of the various factors influencing injury induced by angling.

The experimental angling conducted for this study underlies certain limitations. Firstly, hook sizes varied among study years. However, yearly submodels (not reported in this paper) were applied to confirm the robustness of collected data despite different hook sizes. This supported the assumption that the usage of different hook sizes, ranging from 10 to 18, have no decisive implications on the interpretation of the data collected. Inequality also underlies the number of sessions over days and years, which could have created some spurious interactions. Therefore, certain interactions (e.g. hook size) must not be overinterpreted. The ground bait was also not standardized for the different testing years. But on any given day the amount of ground bait was standardized across experience levels and thus different ground baits between years could not have impacted the present results. Also, for the present study only two systems of water bodies (natural lake and straightened, urban river) were investigated. Therefore, the analyzed data do not allow generalized conclusions on cyprinid fishing. Additionally, both water bodies were fished only in autumn. This is why the results do not allow conclusions on fish behavior and relation to bait changes over all seasons. Finally, experimental effects such as on identifying bleeding due to different experience levels cannot be excluded.

This study shows that the catch per unit effort (CPUE) in open fisheries is linked to the varying experience levels of anglers. Understanding this relationship is crucial for resource managers, as it allows them to use CPUE and angler experience data to estimate fish stock abundance and formulate management strategies aimed at sustaining fish populations. The findings underscore the importance of incorporating novice angler training into recreational fishery management, as less experienced anglers tend to injure more fish but quickly learn to minimize this to a level comparable to that of highly experienced anglers. Training could therefore help reduce fish injury and mortality in catch-and-release fisheries. Additionally, the study found that hook size had minimal impact on catch rates, fish size, bleeding, and hooking depth for float fishing with cyprinids. Consequently, standardizing terminal gear for small-bodied fish may not be essential. Self-identification is validated as an effective method for assessing angling experience in small-bodied freshwater fish, as it correlates well with actual catch outcomes. However, further research with a larger sample size is recommended to better understand the relationship between hook size and bleeding, as this study indicated a weak association where larger hooks were linked to increased bleeding.

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Supporting Information