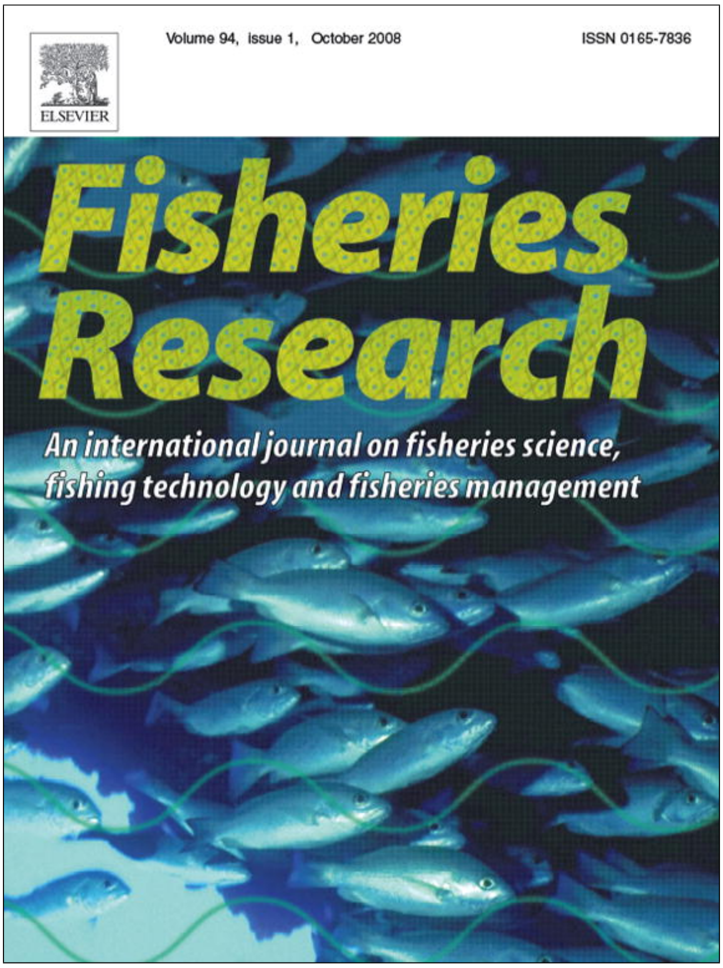
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Exploitation of specialised fisheries resources: The importance of hook size in recreational angling for large common carp (*Cyprinus carpio* L.)

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A B S T R A C T

Little is known about the influence of hook size on fishing success, hooking performance and injury associated with recreational angling for large freshwater fish such as common carp (*Cyprinius carpio* L.). Yet, such information is crucial in the context of the management and conservation of these highly valuable specialised fisheries resources. We compared two different sizes of conventional carp hooks (small, size 6, and large, size 1) baited with corn and found that small hooks caught more and larger carp at similar landing rates. Moreover, small hooks caused less tissue damage compared to large hooks. However, there was no evidence that small hooks reduced incidences of bleeding. For both hook sizes, most carp were hooked in the lower jaw (size 1: 81%; size 6: 64%) and the side of the mouth (size 1: 16%; size 6: 36%), and not a single fish out of 88 fish landed was hooked deeply in vital organs. These results suggest that more widespread use of small size hooks in carp fisheries might be promoted for conservation, fish welfare and angling quality reasons.

1. Introduction

Common carp, *Cyprinus carpio* L., have been widely introduced around the globe to support inland fisheries (Cambray, 2003), and in many European countries they have become a popular target for recreational fisheries (e.g., Czech Republic: Vacha, 1998; Germany: Arlinghaus, 2008; United Kingdom: Hickley and Chare, 2004). Carp angling for rare, exceptionally large trophy fish is becoming popular in continents other than Europe as well (e.g., North America: Cooper, 1987; Farooqi, 2006; Africa: Økland et al., 2003). This kind of recreational fishery also feeds a rapidly developing tourism industry in some countries (e.g. France), and is providing alternative income opportunities for commercially managed water bodies (Arlinghaus and Mehner, 2003).

The consumptive orientation (i.e. the attitude towards catch and harvest aspects of the fishing experience) of carp anglers differs from country to country. In many Eastern European countries carp are often caught for personal consumption (Vacha, 1998). In central Europe and the United Kingdom, highly specialised carp fishing for large carp is often practiced as total catch-and-release angling (North, 2002; Arlinghaus and Mehner, 2003), often involving voluntary catch-and-release (Arlinghaus, 2007). Due to the low mortality rate of caught-and-released carp (Beukema, 1970; Raat, 1985), which can, in fact, be near zero in many situations (T. Rapp et al., unpublished data), and the longevity of carp (>20 years in the wild; McCrimmon, 1968), catch-and-release can result in multiple recaptures of the same individual over time (Hearn, 2000). Given the exceptional emotional and monetary value attached to large carp by individual anglers and fisheries managers (Arlinghaus and Mehner, 2003), it is imperative that the mandatory and/or voluntary release of carp results in the least possible injury to the fish. This is also advisable from a fish welfare perspective that is becoming an increasingly important aspect in recreational fisheries management and conservation world-wide (Arlinghaus et al., 2007a,b; Cooke and Sneddon, 2007).

If inappropriate terminal tackle is used, the repeated capture of an individual fish can lead to cumulative injuries in the mouth and jaw regions (Meka and Margraf, 2007). Indeed, individual carp that are often recaptured may show severe mouth injuries that are very likely associated with previous recapture events. In angling magazines, carp anglers have thus debated the value of small hooks as a means of reducing injuries (Reetz, 2007), as well as the effectiveness of large hooks in terms of landing rates of hooked carp (Janitzki, 2005). There might be a trade-off in optimal hook size related to minimizing injury while maximizing landing success. Currently, however, no study is available to support these

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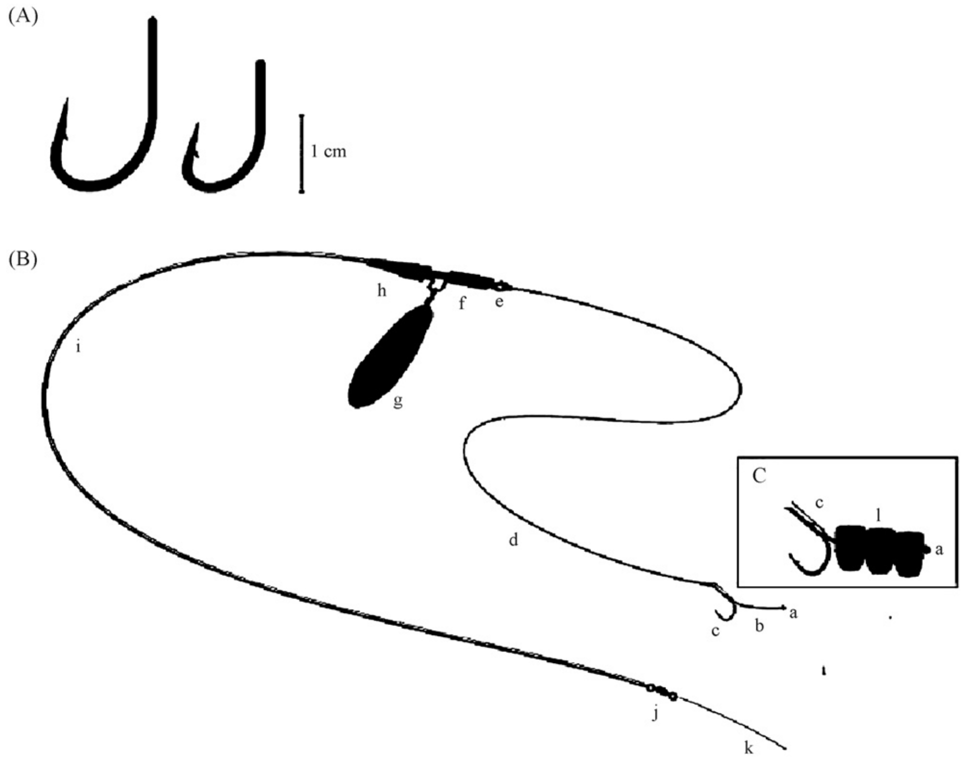

Fig. 1. Illustrations of the hook sizes used in the present study (plot A), the rig used in this study (plot B) and the hair baited with corn (plot C): (a) boilie stopper, (b) hair, (c) hook, (d) leader, (e) swivel, (f) clip, (g) lead sinker, (h) rubber, (i) braided line with a lead core, (j) swivel, (k) braided main line, and (l) corn.

anecdotal claims, which hampers development of scientifically defensible recommendations regarding optimal hook sizes in specialised carp angling. Hence, a field study was completed to determine if there are differences in injuries (i.e., tissue damage and bleeding), capture characteristics and landing probabilities between two popular hook sizes while targeting large carp with specialised carp angling gear designed to mimic real world situations.

2. Methods

The study was conducted on 30 individual fishing days randomly chosen between 11 August and 3 October 2007 at Dow's Lake (N45°23′46.14″, W75°42′03.09″) and the Rideau Canal (N45°23′23.81″, W75°42′05.58″) in Ottawa, Ontario, Canada. During this time period, the water temperature ranged from 18.3 to 24.3 °C (average ± S.E.: 20.8 ± 0.35). All carp fishing was conducted from shore using bottom fishing techniques as it is common for specialised carp angling (Arlinghaus and Mehner, 2003). One type of commercially available carp hook in two sizes was used (Gamakatsu G-Carp Super Hook; sizes 1 and 6; Fig. 1A). These hook sizes represented a common gear choice in specialised carp angling (Steffens and Arlinghaus, 2008). The bait was not directly attached to the hook, but to a short piece of line, which constituted an extension of the leader (Sufix Camo Skin 11.3 kg, Fig. 1B). This so-called "hair" had a length of 2 cm (measured from the bend of the hook) and the leader had a total length of 15 cm. This method is known among carp anglers as the "hair rig" and is assumed to facilitate quick hooking after the bait is sucked as the hook remains uncovered by bait (Fig. 1B, Steffens and Arlinghaus, 2008). For bait, 3 kernels of maize (corn) were used on the hair. They were threaded onto the hair using a crochet hook and fixed on the hair with a small piece of plastic, called a boilie stopper (Fig. 1C).

The leader was directly tied to a swivel (Fig. 1B). A plastic clip was fixed on the swivel, by pushing the swivel into the clip. A lead sinker (weight of 84 g) was attached to the plastic clip and fixed with a flexible cone-shaped rubber tube. The other parts of the terminal rig consisted of a 50 cm long braided line with a lead core to avoid loosing large carp that became snagged in dead woody debris or other structure during the fight. This setup (Fig. 1B) resembled the standard rig and terminal gear used in contemporary angling for large carp that, based on anecdotal evidence, is supposed to improve hooking efficiency and facilitates shallow hooking to minimize injury and increase fish welfare (Arlinghaus, 2007; Steffens and Arlinghaus, 2008). Similar methods contributed to a dramatically reduced depth of hooking in other species (Beckwith and Rand, 2005). The terminal rig was connected to an 18.1 kg test braided mainline via a second swivel (Fig. 1B). On each fishing day, two carp rods (test curve: 1.25 kg, length: 3.60 m) were used at the same fishing site near shore within a macrophyte-free patch. The different hook sizes were randomly allocated to one of the carp rods resulting in the two hooks sizes being offered simultaneously on the fishing spot. The distance between the (rods) hooks was only few meters and the location (either right or left) was determined randomly.

To control for angler skill, all carp were captured by the same experienced angler. All fish were landed with a knotless landing net. After landing, the location of the hook penetration (upper jaw, lower jaw, left corner of the mouth and right corner of the mouth), the absolute hooking depth, the presence or absence of tissue damage and the presence or absence of bleeding were recorded. The absence of tissue damage was defined as lack of additional damage except for the penetration of the hook, which is considered an unavoidable damage in any type of recreational angling. Additional tissue damage consisted of lacerations in the soft mouth tissue as a result of hook movement in the carp mouth. Lacerations

Table 1
Mean total length, catch per unit effort (CPUE), relative hooking depth, relative frequency of bleeding, tissue damage and relative landing probability of carp captured with small (size 6) and large hooks (size 1)

Variable	Size 6	Size 1	*P*-value	Kolmogorov-Smirnov/Levene test	Effect size
Total length (mm)	704 ± 12.1	666 ± 13.9	0.051	Z = 1.269, *P* = 0.08/*F* = 0.58, *P* = 0.45	0.20
CPUE (rod h^{-1})	0.33 ± 0.04	0.25 ± 0.04	0.096	Z = 0.904, *P* = 0.39/*F* = 0.73, *P* = 0.40	0.22
Relative hooking depth	0.0169 ± 0.0013	0.0199 ± 0.0011	0.087	Z = 1.148, *P* = 0.14/*F* = 2.135, *P* = 0.15	0.18
Absolute hooking depth (mm)	11.8 ± 0.80	13.0 ± 0.77	0.33	Z = 1.273, *P* = 0.078/*F* = 5.725, *P* = 0.019	0.11
Bleeding (%)	46	56	0.38		0.09
Tissue damage (%)	30	53	0.036		0.22
Landing probability (%)	82	87	0.37		0.09

For length and relative hooking depth, means ± S.E. are presented. For incidence of bleeding and tissue damage and for the landing probability percent values are displayed. *P*-values and effect sizes are presented as well as results of tests for normality and variance homogeneity.

between 3 and 10 mm were recorded and coded as "tissue damage". In rare events hook penetration resulted in a hole in the mouth tissue when the hook broke through the jaw and appeared completely on the outer side of the jaw. The hooking depth was measured from the anterior end of the jaw to the posterior end of the hook penetration and was corrected for fish size as per Cooke et al. (2001). Bleeding was recorded after the hook was removed. During data sampling we categorized bleeding from 0 to 4 (0 = no bleeding, 1 = light bleeding, 2 = medium bleeding, 3 = severe bleeding). However, unexpectedly hooking depth was shallow in all carp and bleeding was minor overall and only occurred directly at the hooking wound. Therefore, the detailed categorization was collapsed into bleeding absent or present for analytical purposes. No chronic bleeding occurred in our experiment. Additionally, the fish total length was recorded. All measurements were conducted by the same person for all fish. Carp, which could not be landed (i.e. lost after hooking) were also recorded to assess the landing probability of each hook size. During the entire fishing period, there was no by-catch, so it was assumed that every recorded bite would represent a carp. All carp were tagged with individually numbered anchor tags (Floy Manufacturing, Seattle, WA) after capture to rule out the possibility of recapture, and no carp was recaptured during the study period.

For all statistical analyses only carp that were landed were considered, except for the landing probability, which included fish lost relative to those that were landed. To test for differences between the fish total length, catch per unit effort (CPUE, fish rod h^{-1}) and relative depth of hook penetration between the two hook sizes, *t*-tests were used after verifying that the data met the assumptions for parametric tests. The assumption of homogeneity of variances was tested by using Levene's tests, and normality was assessed by Kolmogorov–Smirnov tests. Both assumptions were met in every case (all *p*-values >0.05, see results), except for the absolute hooking depth. Variances were not homogenous between hook sizes for this variable. To account for this, a *t*-test for inhomogeneous variances was used. Categorical variables (presence of bleeding, presence of tissue damage, anatomical location of hook penetration and landing probability) were analysed using χ^2-tests. The software package SPSS (version 9.0) was used for all analyses, and significance was judged at $P < 0.1$. This less conservative significance level relative to $P < 0.05$ was selected to increase the power to detect significant differences (Huberty, 1987) due to the low sample size. Sample size could not be increased as winter approached and catch rates dropped dramatically.

To judge the magnitude of the differences in the response variables between the two hook sizes, for every analyzed parameter effect sizes (either r for metric variables or φ for categorical variables) were calculated (Cohen, 1988). Gliner et al. (2001) recommended to report effect sizes in addition to significance values to allow better interpretation of the magnitude of the difference. Reporting effect sizes also improves the possibility for future meta-analyses (Cohen, 1988; Gliner et al., 2001).

3. Results

In total, 88 carp were captured. Of these, 56 fishes were captured on hooks of size 6 and 32 fish on hooks of size 1. The total length of the carp landed ranged from 486 to 930 mm. The CPUE was significantly higher for small hooks than for large hooks (Table 1). Moreover, carp captured on small hooks were significantly larger than those captured on the large hooks (Table 1). There was no difference in the probability of landing a carp among hook types and overall, a large fraction (84%) of carp that were hooked was also landed (Table 1)

Relative depth of hook penetration differed significantly between hook sizes. Larger hooks tended to be hooked more deeply than smaller hooks (Table 1). However, there was no difference in absolute hooking depth between hook sizes (Table 1). Anatomical location of the hook penetration significantly differed between the hook sizes ($\chi^2 = 6.376$, d.f. = 3, $P = 0.095$, $\varphi = 0.27$, Fig. 2). Large hooks were more likely to be hooked in the lower jaw than small hooks, but the lower jaw constituted the by far most common hooking location for both hook sizes (>64% for both hook sizes). Not a single carp was hooked deeply in vital organs (Fig. 2). Bleeding of carp was similar for both hook sizes with roughly half of the fish captured bleeding slightly at the hook wound (Table 1). For both hook sizes no differences in bleeding frequency in the different hooking locations were observed (size 6: $\chi^2 = 0.519$ d.f. = 1, $P = 0.47$, $\varphi = 0.1$; size 1: $\chi^2 = 2.484$, d.f. = 2, $P = 0.29$, $\varphi = 0.27$). Despite no difference in bleeding relative to hook size, a greater fraction of carp captured with large hooks had injuries (e.g. tissue tearing beyond the typical hook penetration) than carp captured with small hooks (Table 1). Frequency of injuries was unrelated to the anatomical hooking location (size 6: $\chi^2 = 0.002$, d.f. = 1, $P = 0.97$, $\varphi = 0.01$; size 1: $\chi^2 = 1.617$, d.f. = 2, $P = 0.45$, $\varphi = 0.22$).

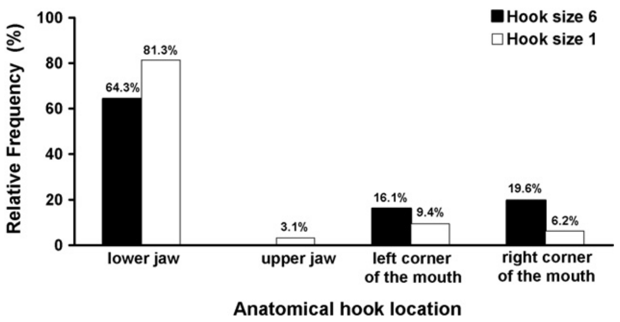

Fig. 2. Percentage of carp hooked in different anatomical hooking locations by hooks of sizes 1 and 6.

4. Discussion

Much attention has been devoted to the evaluation of the performance and injuries associated with different hook designs (e.g., circle hook versus "J"-type hook) for freshwater species in a recreational fisheries context (Cooke and Suski, 2005), but less attention has been paid towards the impact of different hook sizes (Cooke et al., 2005; Cooke and Sneddon, 2007). Our study revealed that hook size influenced catch rate, fish size, relative hooking depth, anatomical hooking location and frequency of injuries for carp. The results unequivocally showed that small hook sizes (size 6) were superior to large hook size (size 1) in carp angling with corn using fixed leads and hair rigs. Small hooks captured higher numbers of carp as well as larger carp. Similar results were found in a marine longline fishing context where more fish were landed on smaller hooks (Erzini et al., 1998).

It is important to realize that gape size limitations, potentially preventing successful ingestion of large hooks, is likely not responsible for the observed differences in carp angling in our study. Both hook sizes used in the present study were small compared to the large gape of the carp. The higher fishing efficiency of small hooks in the present study may be related to the differential weights of the different hooks and the way carp ingest particulate food. Carp feed on such food through a fast and voluminous expansion of the oropharyngeal and opercular cavities that causes a suction flow facilitating the uptake of particulate food such as corn from a distance within the headlength of the fish (Sibbing, 1988). Presumably, carp in the present study were preconditioned to feed on corn as corn was also offered as groundbait and thus was available in large numbers at the fishing site because this is typical in specialised carp angling (Arlinghaus and Mehner, 2003; Niesar et al., 2004; Arlinghaus and Niesar, 2005). Accordingly, carp might have adjusted the suction strength to the weight of the corn. A larger and hence heavier hook might have interfered with normal feeding patterns, which in turn might explain its reduced fishing efficiency. The fact that small size hooks fished with corn caught larger and more fish is likely to be well received by specialised carp anglers as these anglers value size of fish to a great extent (Arlinghaus and Mehner, 2003)

In the present study, the hook size also influenced relative depth of hook penetration. Carp captured with small size hooks were hooked shallower than fish captured on larger hooks, but this did not result in a larger fraction of lost carp. This is atypical compared to the results reported in other studies where smaller hooks have tended to hook the fish more deeply (e.g. Cooke et al., 2005; Grixti et al., 2007). However, there was no difference in absolute hooking depth between large and small hooks in our study. Therefore, the differences in relative hooking depth between large and small fish very likely results from the fact that smaller hooks caught larger fish resulting in shallower relative hooking depth in small hooks compared to large hooks. All carp in the present study were hooked in the lips or the buccal cavity and not in vital organs, which was likely the result of the type of terminal gear used. Our results were in agreement with the anecdotal evidence in the specialised carp angling literature that promotes use of fixed and heavy weight on the line and a so-called hair rig to avoid deep hooking in angling for benthivorous fish species (Steffens and Arlinghaus, 2008). Indeed, Beckwith and Rand (2005) verified this pattern in recreational fishing for red drum (*Sciaenops ocellatus*). Shallow hooking is important for minimizing the risk of hooking mortality that is often associated with deep hooking (Pelzman, 1978; Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2008), and our results support the notion that modern carp angling techniques are effective in this regard.

In our study, we documented that smaller hooks tended to be less injurious to fish than larger hooks. This can be partly attributed to the larger wound that is caused by a larger hook size, particularly when using barbed hooks as in this study. Our findings are in accordance with anecdotal observations made by carp anglers and published in angling magazines (Reetz, 2007) and also agree with reports on several saltwater species documenting the positive relation between hook size and severity of mouth injury (Mapleston et al., 2008). Thus, permanent damage to the mouth of a carp through repeated capture of the same carp over time will be more likely to occur when using hooks of large size. Repeated piercing of mouth tissue over time can result in a complete loss of the side part of the jaw, which can reduce the aesthetic value of these specimens for the anglers (Meka, 2004). This can also be a vehicle for infections (Meka, 2004) or lead to feeding impairments, which can increase the likelihood of fitness impacts or ultimately result in death (Arlinghaus et al., 2007b; Cooke and Sneddon, 2007).

In conclusion, the presented findings suggest that hooks of a small size are beneficial in carp fisheries as they cause less injury and catch more and bigger fish, without sacrificing landing rates. However, from a conservation perspective, it is important to note that smaller hooks, at least when fished with corn, result in higher catch rates so an overall smaller injury rate might be compensated by a higher fraction of the stock captured. However, given that smaller hooks caught larger carp (which are of particularly high value from the social point of view), anglers will likely adopt these smaller hook sizes. Our results collectively suggest that smaller hook sizes might be of conservation value for carp fisheries. They also cause less injury and are therefore preferable to large hooks from a fish welfare perspective (Arlinghaus et al., 2007a). Promotion of the use of small hooks in specialised carp angling can be of importance in heavily fished water bodies and those commercially operated as total catch-and-release, where availability and conservation of healthy and injury-free large carp is of high priority. Further studies are needed to understand whether the trend observed in the present study persists with even smaller hook sizes and with different baits used as the benefits of small hooks might be a function of bait size and bait type and the associated feeding pattern of carp.

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