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Short communication

Effects of landing net mesh type on injury and mortality in a freshwater recreational fishery

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Abstract

Landing nets used by recreational anglers can be constructed of a variety of different mesh materials. Anglers and fisheries managers have hypothesized that mesh type may affect injury rates and fish survival. To test this hypothesis, we used bluegill (*Lepomis macrochirus*) as a model species to examine the effects of different net mesh types (rubber, knotless nylon, fine knotted nylon, coarse knotted nylon) on injury and mortality following angling at 26 °C. A control group consisted of individuals that were angled and held out of the water but not netted. Retention in a landing net for 30 s resulted in increased pectoral and caudal fin abrasion relative to control fish. Furthermore, evidence of dermal disturbance (i.e. scale and/or mucous loss) was more prevalent in netted fish than in control individuals. No control fish died during a 168 h holding period, whereas mortality rates ranged from 4 to 14% for fish landed with nets, and the majority of mortality occurred between 48 and 96 h post-treatment. Fish that died exhibited impaired swimming behavior for approximately 24 h prior to death that was attributable to the extreme caudal fin erosion. Fish that died also had Saprolegnian lesions on the caudal peduncle that had begun to progress anteriorly toward the gills. Our results indicate that fish captured and landed by hand had lower injury rates than those fish landed using a net and experienced no mortality. Conversely, all net types resulted in heightened injury and mortality with the knotted mesh types being more injurious than the rubber or knotless mesh. This study supports the hypotheses that landing nets injure fish, and that mesh type alters the severity of injury. We urge further study using larger species of fish that are commonly landed using these gear types.

Keywords: Netting injury; Recreational angling; Landing net; Bluegill; Gear effects

1. Introduction

Landing nets are commonly used by recreational anglers to aid in the capture of many species of fish (Quinn, 1993). Nets offer a simple and effective means of retrieving angled fish from the water, putting them into the control and possession of the angler without imparting undue stress on the fishing rod. The netted fish appear protected and restrained from injury that would result from physical contact with the bottom of a boat or a terrestrial environment. In most cases, fish manifest few obvious immediate effects of the netting process, and when released, swim away in seemingly good condition. This leads anglers and managers to conclude that the total costs of the angling interaction for the fish consist of the energy expended in the

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struggle, the sub-lethal physiological disturbance from exercise, and associated hooking injury (Muoneke and Childress, 1994; Cooke et al., 2002). Anglers and fisheries managers rarely consider the potential influence of landing nets and mesh type on injury and mortality, and to date, there have been no studies that have investigated these possible effects.

In a cursory survey of popular outdoor media, conservation organizations, and natural resource management agencies using web-based searches, there were disparate opinions on the use of landing nets. In some instances the use of nets was encouraged or mandated. This is especially common in Western Europe where landing nets, including specific mesh types, are often considered a statutory requirement. More frequently, however, the use of landing nets was discouraged or prohibited despite a lack of empirical scientific data. The prohibition of landing net use in these situations reflects the notion that increased injury and mortality may result from their use (Quinn, 1993). Landing nets could potentially abrade fins and lead to loss of scales and mucous from the body of the fish. Guides to the care of fish for research suggest that fish should be netted as infrequently as possible and using soft mesh preferentially (e.g. Kelsch and Shields, 1996), adding further support to the potential negative consequences of using nets. Researchers have determined that substantial injury and mortality can result from abrasion in pot-trapped fish (Cooke et al., 1998), tournament angled fish (Steeger et al., 1994), and in fish retained in wire baskets (Cooke and Hogle, 2000) and keep nets (Raat et al., 1997; Pottinger, 1997; Cooke and Hogle, 2000). While these handling processes and gears differ in form and function from landing nets, they all have abrasive surfaces that physically contact the fish's body. Landing nets may impart similar injuries that could result in death.

Landing net mesh can vary by material, mesh weave, and mesh size, although the most common types used in recreational angling are soft knotless nylon, thick rubber, and knotted polypropylene. Some net manufacturers market nets with mesh types that they claim will reduce injury, such as soft knotless nylon or rubber. Despite a large body of anecdotal information emanating from angler opinion and outdoor media (e.g. Quinn, 1993), we were unable to find any reports that examined the effects of net use and type of mesh on injury and mortality of fish. In response, our objective was to assess the effect of different types of commonly used landing net mesh configurations on the injury and mortality of bluegill as a model for other freshwater recreational fisheries. We angled fish and retained them using landing nets with four different mesh types (knotless nylon, rubber, and small and large knotted polypropylene) for 30 s and observed and enumerated injury and mortality that resulted. We compared these injury and mortality rates with control fish that were held out of water for the same period, but not placed in a net. For these experiments, we used bluegill as a model due to their high abundance in many freshwater systems. Although these results will be useful for anglers and fisheries managers, these data will also be relevant to fish culture personnel or anyone dealing with fish husbandry.

2. Materials and methods

2.1. Study site and experimental animals

All fish used in this study were captured from Lake Opinicon, Leeds County, east-central Ontario, Canada (44°34′N, 76°19′W). The mean depth of the lake is 2.5 m, with much of the extensive littoral zone supporting beds of vegetation and abundant populations of bluegill (Keast, 1978). Experiments were conducted on a single day (20 June, 2001) with a surface water temperature of 26 °C and air temperatures of 25–28 °C. All fish were angled from either a 4 m barge or from docks extending into the lake.

Although bluegill are not so large or rare that a net is required to land them effectively, they still served as an ideal test species due to their overall abundance and ease of capture. Bluegill also are the target of a large catch-and-release fishery in many parts of North America (Coble, 1988). Furthermore, we have recently completed a study investigating bluegill hooking injury and mortality rates at 26 °C (Cooke et al., 2003). These data were useful for choosing appropriate terminal tackle and for providing insight into background angling and hooking related injuries and stresses.

2.2. Experimental approach

Bluegill were angled using circle hooks (size 6, Owner Inc.) baited with an organic bait (Berkley

Crappie nibbles, Berkley Inc.). Circle hooks are designed to reduce hooking mortality and injury by preventing deep hooking of fish (Cooke et al., 2003). A small lead sinker was attached to the line 15 cm above the hook, and a cork bobber was fixed at differing distances from the hook depending on the depth of the water. The hook was set when the entire bobber was pulled and held below the surface of the water. The hooked fish were then brought directly to the angler and subjected to one of the four experimental treatments (net types) or to the control treatment. The net types chosen reflected those commonly used by recreational anglers, are readily available at tackle shops, and all nets were of approximately the same size. The type of mesh was the only functional difference between the four net types. The square mesh measurements were as follows: rubber, 10 mm; knotless nylon, 4 mm; fine knotted polypropylene, 10 mm; and coarse knotted polypropylene, 20 mm (Fig. 1). The diameter of the rubber mesh was 4 mm, while the knotless, fine and coarse knotted mesh types had a 1 mm diameter. The knots in the fine knotted and coarse knotted mesh types had diameters of 2 and 4 mm, respectively.

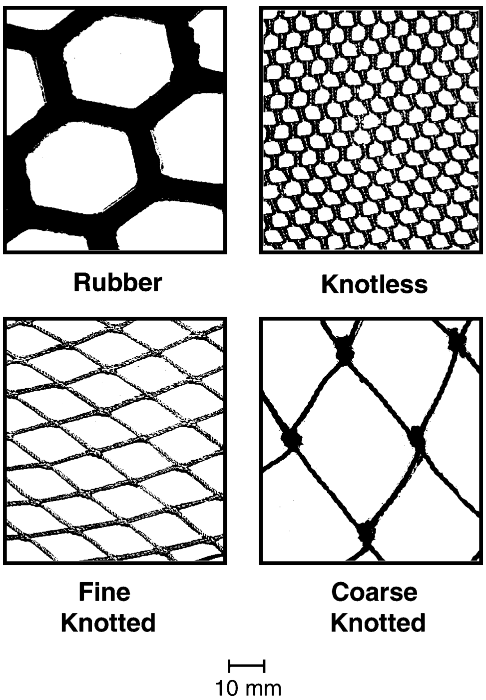

Fig. 1. Graphical depiction of landing net mesh types used in experiment.

For each of the experimental treatments, fish were hooked, reeled to the boat or dock, removed from the water using one of the different net types (or no net in the case of the control), and held in the net exposed to air for a period of 30 s. The time held out of the water, either in or out of a net, was meant to mimic the time it might take a recreational angler to remove a hook and release the angled fish back to the water. The experimental and control treatments were rotated so that each angled fish received a different treatment than the one that preceded it, and every fifth fish was considered as the control. Following the 30 s holding period, fish were removed from the hook and passed to a sampling station for measurements, and to receive identification clips. To minimize background injury and mortality, we released bluegill that were not hooked in the upper lip or roof of the mouth.

Recorded measurements consisted of the total length of the fish to the nearest millimeter, and two different classes of injury resulting from the net. First, we quantified the number of small and large abrasions in both the caudal and left pectoral fins. Small abrasions, according to our definition, did not reach the proximal edge of the fin, whereas large abrasions spanned the entirety of the fin from the distal tip to the proximal edge. Second, we performed an assessment of dermal disturbance, and ranked fish as either 1, 2 or 3 depending on the amount of disturbance visible. A score of “1” indicated very minor dermal disturbance, such as slight mucus loss, whereas a score of “3” indicated major disturbance to the natural dermal condition of the fish, such as scale and mucous loss. The score of “2” was intermediate, with some loss of scales and dermal mucus, but only in moderate amounts.

Individuals were identified by administering a single sequential clip to the dorsal spines of fish that were caught. By administering such clips, it was possible to indicate which treatment (net type) each fish received. The entire hook removal and enumeration process took less than 60 s to perform, thereby limiting the amount of additional air exposure.

Following measurements and identification clips, fish were held in a 300 l holding tank for a period of no more than 2 h, during which time the water was frequently cycled with ambient lake water. Fish were then transferred to a 16 m^3 enclosure in the lake (without the use of nets), where they were held for 168 h. The bottom of the enclosure consisted of scattered gravel and pebble substrates in the littoral zone and floating vegetation, as well as several larger rocks that provided some cover for the fish. Fish found dead or near death during the 168 h monitoring period were collected, measured, and inspected for individual spine clips, making it possible to determine the treatment of each dead fish. We then measured the total length of the fish (mm), recorded notes on the condition of the fish, and quantified the degree of fungal infection as proportion of the body covered by lesions. At the termination of the 168 h retention period, all remaining fish were released.

2.3. Analysis

Data were assessed for normality using normal probability plots, Shapiro–Wilk W tests. Homogeneity of variances were assessed using the Levenes test. When data were normal and homogeneous in terms of variance, we used a one-way analysis of variance (ANOVA) and the conservative Tukey Post-Hoc test to test for differences in continuous variables (i.e. total length, caudal fin abrasions, pectoral fin abrasions) between treatments. Contingency table analysis was used to test for differences in dermal disturbance rates (categorical data) between treatments. We used least squares regression to assess the relationship between total length and both rates of caudal and pectoral fin abrasion. Mann–Whitney U tests were used to test for differences between the size of fish that died or survived during the retention period. For all analyses, we present means ± S.E. and assess significance at $\alpha = 0.05$.

3. Results

3.1. Injury rates

The total length of bluegill was similar between all treatment groups ($F = 0.1582$, $P = 0.959$) (Table 1). Overall, the amount of pectoral fin abrasions differed by mesh type ($F = 4.1633$, $P = 0.003$), however, there was only one pairwise difference (Fig. 2). Fine knotted mesh had significantly higher pectoral fin abrasions (0.16 ± 0.052) than control fish (0 ± 0) ($P = 0.016$). The amount of caudal fin abrasion was strongly influenced by mesh type ($F = 44.1386$, $P < 0.001$) (Fig. 2). In general, coarse knotted mesh was more injurious than all other mesh types. Although fine knotted mesh also resulted in large amounts of fin abrasion, it was not significantly different from rubber mesh. Knotless and control fish had similarly low rates of caudal fin abrasion.

Table 1
Total length (mm) of bluegill exposed to different landing net treatments (total mortality following a 168 h retention period was also calculated)

Treatment	N	Mean total length (mm) ± S.E.	Total mortality (%)
Control	50	130 ± 4.2	0
Rubber	50	135 ± 3.9	4
Knotless	50	132 ± 4.3	6
Fine knotted	50	132 ± 4.2	14
Coarse knotted	50	134 ± 4.7	10

Dermal disturbance immediately following treatments was also influenced by mesh type ($\chi^2 = 46.007$, $P < 0.001$). Knotless, rubber, and control fish had similarly low rates of dermal disturbance, whereas, coarse and fine knotted mesh resulted in higher rates of dermal disturbance. The size of the fish was generally independent of the amount of abrasions in both the pectoral and caudal fins. The only significant relationship was for control fish and caudal fin abrasion rates ($R^2 = 0.11$, $P = 0.020$), with larger fish having more abrasions than smaller fish. None of the control fish exhibited pectoral fin abrasion, prohibiting testing for size specific trends within this group.

3.2. Mortality rates

Although incidences of mortality were generally low (i.e. <14%) across all types of mesh, some differences were noted (Fig. 3). Throughout the retention period, no control fish perished. Fish landed with knotless mesh and rubber mesh exhibited mortality rates of 6 and 4%, respectively. The highest levels of mortality were observed in fine knotted (14%) and coarse knotted (10%) mesh types. All mortality occurred between 48 and 120 h post-treatment. Overall, no size specific trends in mortality were evident ($U = -1.802$, $P =$

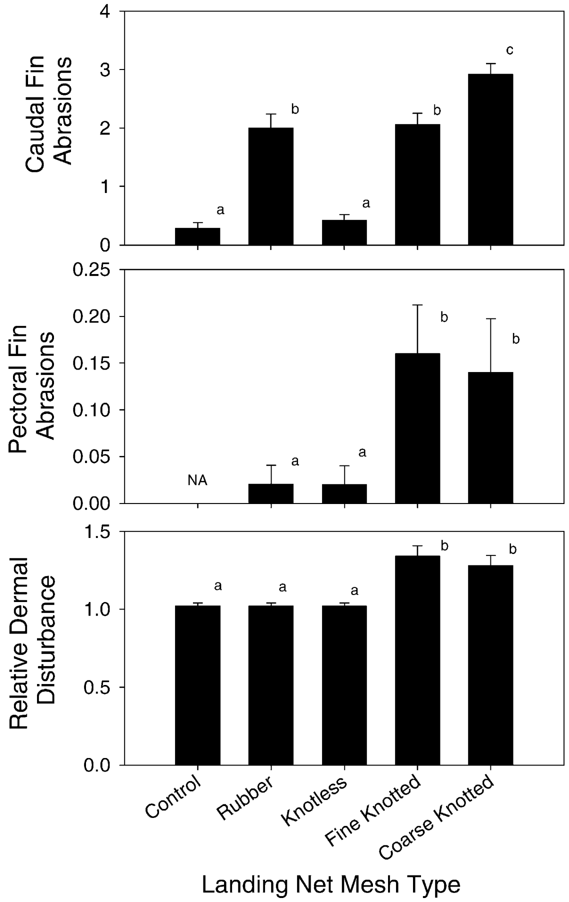

Fig. 2. Rates of injury associated with different netting treatments and controls for bluegill immediately after treatment and prior to retention. The uppermost panel represents caudal fin abrasion rates, the middle panel represents pectoral fin abrasion rates, and the lower is the mean dermal disturbance rate. Note that dermal disturbance was categorical data and analyses were conducted in accordance with this. Control fish for pectoral fin rates were excluded from analysis due to no variance (i.e. all values = 0). For all panels, dissimilar letters represent significantly different values ($P < 0.05$). All values are means ± S.E.

0.238). Saprolegnian lesions were present on all fish that died and covered between 5 and 15% of the body of moribund fish (Table 2). All fish that died exhibited extreme levels of caudal fin abrasion. In fact, most of the caudal fins had eroded to the caudal peduncle. All dead fish exhibited loss of scales and mucous and were observed to swim erratically for a period of ∼12 h prior to succumbing to their injuries. Too few fish died to permit rigorous quantitative analysis (Table 2).

4. Discussion

The data presented in this paper are the first empirical assessment of the effects of different landing net mesh types commonly used by recreational anglers on the injury and mortality of freshwater recreational fish. Our results indicate that fish exposed to any of the four netting treatments exhibited some degree of pectoral and caudal fin abrasion as well as a level of dermal disturbance greater than that of control fish, but the degree of incidences of injury and mortality varied with net type. In general, the coarse and fine knotted net types were the most injurious and consistent with this, produced the highest levels of mortality. Although rubber and knotless netting were less injurious than both knotted types, injury rates were higher than control fish. Despite having lower injury rates, fish netted with rubber and knotless mesh both exhibited mortality, albeit lower than knotted mesh types.

In our study, the amount of caudal fin abrasion was strongly influenced by mesh type. The knots and general configuration of the coarse and fine mesh types were damaging to the caudal fins of bluegill. The coarse knotted mesh was the most injurious, followed by the fine knotted mesh and the rubber mesh. Knotless mesh type had low caudal fin abrasion rates similar to levels observed in the controls. All fish that died in our study exhibited extremely eroded caudal fins that resulted in impaired swimming performance. Although extreme erosion was only observed in fish that perished, it is possible that high rates of fin abrasion that did not directly induce mortality may have led to less obvious sub-lethal effects. These effects include increased susceptibility to predation or passive displacement in lotic flows or lentic currents, and well as reduced efficiency at acquiring food.

We also quantified the degree of pectoral fin abrasion as these structures are involved in fine scale locomotory movements and in the parental care phase for males of this species. In our study pectoral fin abrasion was generally low, although the fine knotted mesh did induce more abrasions than observed in control fish. The amount of pectoral fin abrasion may be low across all mesh types due to the size of the pectoral fins relative to the mesh sizes. The knotless mesh caused substantial pectoral fin abrasion, whereas the rubber and coarse knotted mesh were too large to permit this. The minimal amount of fin abrasion observed

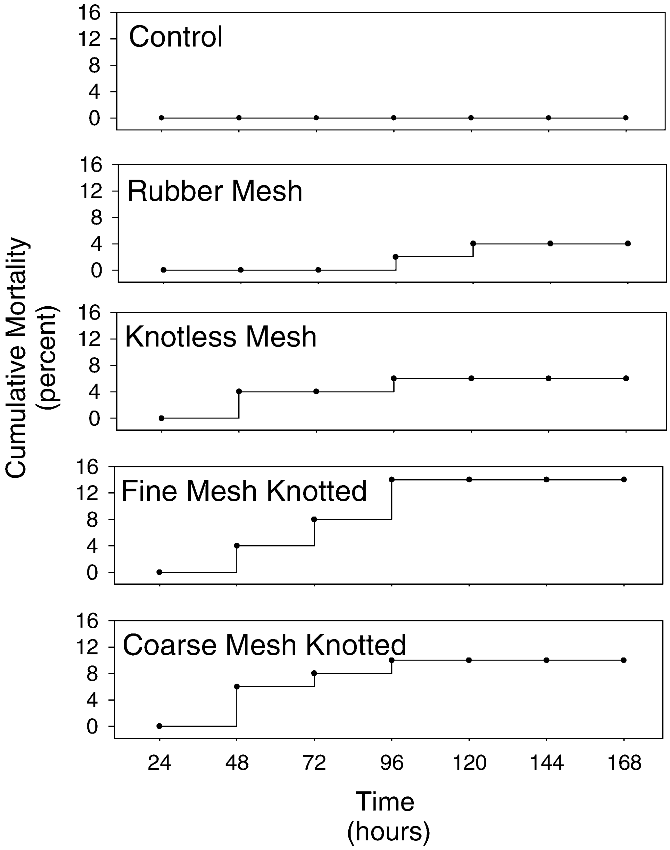

Fig. 3. Cumulative mortality of bluegill exposed to four different netting treatments. The uppermost panel is the control group. Fish were held for 168 h in a large enclosure to document mortality patterns.

in control fish was likely the result of background fin abrasion experienced during day to day activities. In fact, the only significant relationship between rates of fin abrasion and total length were observed for control fish and pectoral abrasions. This is likely the result of older, larger fish having had more exposure to natural environmental conditions where fin abrasion occurs.

The amount of dermal disturbance (composite of scale and mucous loss) also varied across treatments with fine knotted and coarse knotted mesh exhibiting high levels relative to knotless and rubber mesh types and control fish. Previous studies have documented that substantial injury and mortality can result from dermal abrasions from a variety of sampling and retention gear due to the proliferation of saprolegnian infections (Cooke et al., 1998; Cooke and Hogle, 2000; Raat et al., 1997; Pottinger, 1997). *Saprolegnia* spp. is typically associated with wounds resulting from handling and other forms of epidermal trauma (Wolke, 1975; Richards, 1978). The mucous layer covering the dermal surface of the fish acts as a physical barrier to colonization by foreign organisms and possesses anti-fungal properties (Tiffney, 1939). Following an incident of dermal disturbance and infection, the fungal lesions spread across the surface of the fish. Saprolegnian lesions were present on all fish that died in our study and covered 5–15% of their bodies. The knotted mesh types have a higher incidence of dermal disturbance (i.e. loss of mucous and scales) that apparently promote fungal infection in netted fish.

Mortality rates observed in our study were generally low, although all mesh types produced more mortality than found in control fish. Because so few fish died, it

Table 2
Meristics and characteristics of individual bluegill that perished during the 168 h retention period

Treatment	Total length (mm)	Caudal abrasions (#)	Pectoral abrasions (#)	Dermal disturbance (relative)	Fungal lesions (% of body)	Time of death (hours from netting)
Rubber	114	Few	None	Little	5	96
Rubber	116	Few	None	Moderate	10	120
Knotless	127	Moderate	None	Little	5	48
Knotless	106	Moderate	Few	Moderate	5	48
Knotless	126	Few	None	Moderate	15	96
Fine knotted	142	Moderate	Few	Moderate	10	48
Fine knotted	112	Moderate	None	Moderate	5	48
Fine knotted	106	Moderate	None	Moderate	15	72
Fine knotted	152	Few	None	Moderate	5	72
Fine knotted	127	Moderate	None	Moderate	5	96
Fine knotted	111	Moderate	None	Moderate	10	96
Fine knotted	122	Moderate	None	Moderate	5	96
Coarse knotted	118	Moderate	None	Moderate	5	48
Coarse knotted	112	Moderate	Few	Moderate	15	48
Coarse knotted	116	Moderate	None	Moderate	5	48
Coarse knotted	119	Moderate	None	Moderate	10	72
Coarse knotted	106	Moderate	None	Extreme	15	96

is difficult to present a quantitative assessment of the characteristics of fish that perished. Although we did not observe any clear patterns among the sizes of fish that died and those that survived, we suspect that if larger fish were netted, their larger mass could result in increased levels of fin abrasion. Heavier fish held in the same nets would exert more pressure on their caudal fins. The increased thrashing of larger, stronger fish inside the net could also result in both increased abrasion damage as well as heightened levels of dermal disturbance. In recognition of this, muskellunge anglers typically use a cradle device constructed with knotless mesh to restrain the fish in the water to facilitate hook removal. The size and ferocity of muskellunge and the associated difficulties in handling them had prompted anglers to try alternatives to conventional nets. In our study, the indicators of physical disturbance (i.e. caudal abrasion and dermal disturbance) were higher in fish landed with nets, suggesting that the mortality we observed was a direct result of injuries induced by netting.

Because fish exposed to each of the four mesh types in our study sustained more injury than control fish that were not exposed to any mesh type, our empirical data suggest that whenever possible, anglers should attempt to avoid using landing nets. When deemed essential, we strongly urge anglers to use either rubber or knotless nylon mesh types. While these differences are apparently recognized by the aquaculture industry and strongly conservation minded anglers, our results will hopefully promote dissemination of these ideas to a wider group of stakeholders. Indeed, knotless mesh netting is the standard in modern aquaculture and for fish handling in research (Stickney and Kohler, 1990). Although there had not been a formal comparison of mesh types prior to this study, the aquaculture industry had been operating for many years on the assumption that knotless mesh was less abrasive and damaging to fish than other mesh types. The information that we present here holds value for all recreational fisheries, but particularly those that receive heavy fishing pressure or that consist of species that are sensitive to injury. We recognize that in some instances netting is required to safely land and control fish to prevent mechanical injury to the fish, and netting is apparently a better alternative to other options. We advocate that anglers and management agencies consider the trade-offs between injuries resulting from net use and the potential for injury when landing nets are not used. We believe future investigation into the relationship between mesh type and injury in larger fish would be valuable.

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