Fisheries Research 113 (2012) 147–152

Contents lists available at SciVerse ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

The influence of hook size, type, and location on hook retention and survival of angled bonefish (*Albula vulpes*)

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ARTICLE INFO

Article history:
Received 7 June 2011
Received in revised form 25 October 2011
Accepted 1 November 2011

Keywords:
Best practices
Bonefish
Catch-and-release
Hook retention

ABSTRACT

Bonefish (*Albula* spp.) support a circum-tropical sport fishery in which anglers predominantly release angled fish. The influence of hook location, size, and type on hook retention, post-release feeding ability and survival were evaluated. Overall, 46% of bonefish held in large holding tanks expelled hooks within a 14-day observation period. Hooks located in the lip were expelled 2.6 times more frequently than hooks located in the gut. Barbless hooks were expelled 3.9 times faster when located deep in the oral cavity compared to barbed hooks, but there was no difference in expulsion rates among barbed and barbless hooks in shallow-hooked fish. For the two hook sizes studied, hook size had no impact on hook expulsion rates or duration of hook retention regardless of hook location or type. The presence of a hook had no significant effect on weight change, indicating the presence of a hook did not impede feeding ability. No post-release mortality was observed for bonefish during the short duration of this study. Leaving a difficult to remove hook in a bonefish is recommended to increase the likelihood of post-release survival, especially in cases where the threat of bonefish predators is high.

1. Introduction

Hooking is an unavoidable consequence of a catch-and-release angling event, and has the potential to cause tissue damage for fish that have been caught (Cooke and Sneddon, 2007). In many situations, fish are hooked in the lip or corner of the mouth, which can make hook removal prior to release easy, rapid, and likely minimizes major tissue damage. In some instances, however, hooks are ingested deeply by fish with hooking occurring in the gut or esophagus. Several syntheses and meta-analyses have revealed that deep hooking is one of the most important predictors of immediate and short-term mortality among angled fish (Arlinghaus et al., 2007; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Cooke and Wilde, 2007; Muoneke and Childress, 1994). In these situations, anglers intending to release their catch are faced with a quandary. Anglers could work to remove hooks from the esophagus of deeply hooked fish, but this may involve additional trauma, air exposure and excessive handling, all of which have been shown to negatively impact survival (reviewed in Cooke and Suski (2005)). Alternatively, anglers may choose to release deeply hooked fish with the hook still in the fish's tissue, but there is potential for reduced survival rates due to the presence of the hook (Arlinghaus and Hallermann, 2007).

To date, there have been several studies for a range of marine and freshwater species that have investigated the effects of leaving deeply set hooks in place, as well as the post-release effects of removing deeply set hooks. Some studies have indicated that fish mortality is reduced when fish are released with the deep hook left in the animal compared to having anglers perform lengthy (and potentially damaging) hook removal procedures (Fobert et al., 2009; Mason and Hunt, 1967; Warner, 1979), or that there is no difference in survival between fish released with or without hooks in place (e.g., Wilde and Sawynok, 2009). Other studies have shown that some fish are capable of expelling hooks that are not removed (Aalbers et al., 2004; Diggles and Ernst, 1997; DuBois and Pleski, 2007; Schill, 1996; Tsuboi et al., 2006), although the time between deep hooking and evaluation of retention varies widely among studies. However, releasing angled fish with deep hooks in place may negatively affect food consumption and growth (Aalbers et al., 2004; Schisler and Bergersen, 1996), and may also have a number of pathological consequences (e.g., Borucinska et al., 2001, 2002), both of which can have negative consequences for released fish. Collectively, the evidence from these disparate studies suggests that injuries resulting from hook removal may be a greater threat for

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doi:10.1016/j.fishres.2011.11.001

survival than the consequences of releasing fish with hooks in place. Development of a clear recommendation regarding hook removal in released fish requires a better understanding of the effects of hook retention on survival as well as feeding ability and growth. Studies to date have focused on a narrow range of species, as well as a limited number of hook types, precluding broad recommendations that transcend species and different angling techniques (Cooke and Suski, 2005).

Bonefish are a common target of recreational anglers in shallow tropical marine waters, and healthy bonefish fisheries can generate millions of dollars for local economies (Fedler, 2010). Specialized anglers who target bonefish commonly adopt a strong conservation ethic that emphasizes minimal individual- and population-level consequences of angling, and results in estimated release rates of over 90% (Policansky, 2002). Anglers target bonefish using both large, baited hooks, as well as fly-fishing gear using smaller hooks, and a significant but unquantified proportion of bonefish anglers use barbless hooks to facilitate release. More importantly, bonefish can break the line during an angling event and swim away with a hook still in their tissue. In some cases, anglers have been known to intentionally break their line by tightening their drag, particularly in instances when a predator (e.g., lemon shark *Negaprion brevirostris*) is chasing the bonefish during the fight. Intentional line breaking presumably enables the fish to escape prior to being exhausted by the angling event and reduces the likelihood of shark predation (Danylchuk et al., 2007a,b). The consequences of hook retention on these fish are not known, particularly in situations where fish have been deeply hooked, precluding recommendations to anglers and managers on practices that can maximize survival of angled bonefish. A mail survey of bonefish anglers in Florida revealed that anglers were willing to alter behavior and gear choice to reduce hooking mortality where supported by scientific study (Larkin et al., 2010).

The objective of this study was to quantify the consequences of hook retention on the survival and feeding performance of bonefish and to determine if these responses were influenced by hook type, hook size and/or hook location. This study attempted to simulate techniques used in both fly angling and bait fishing. In fly-fishing, anglers typically use small barbless hooks and in bait fishing anglers tend to use larger barbed hooks. Therefore two hook types (barbed and barbless), two hook sizes (small and large) and a shallow (i.e., upper jaw) and deep (esophagus) hooking location were compared.

2. Methods

2.1. Field collection

Between October 2009 and January 2010, wild bonefish (*Albula vulpes*, Albulidae) were captured from small tidal creeks near Cape Eleuthera, The Bahamas (24.54°N, 76.12°W) using a large mesh seine ($n = 91$). Fish were transported to the Cape Eleuthera Institute (CEI) and placed in large circular holding tanks (3.7 m diameter × 1.25 m height; 13,180 L) that were aerated and continuously supplied with fresh seawater at a rate of approximately 1800 L/h (Danylchuk et al., 2007a; Murchie et al., 2009). Fish were given at least 24-h to acclimate to laboratory conditions before any experiments were initiated. All research was conducted in accordance with the policies of the University of Illinois Institutional Animal Care and Use Committee (Protocol #09232).

2.2. Study design

To quantify the influence of hook size, type, and location on hook retention, mortality and feeding performance, bonefish (fork length range 310–484 mm) were assigned to one of the seven treatment groups ($n = 13$ individuals per treatment group) designed to replicate parameters that could be experienced by bonefish caught during an actual angling event. Two sizes of commercially available "J" hooks (size #6, length = 38 mm, maximum width = 10 mm and size 1/0, length = 20 mm, maximum width = 5 mm) representing sizes typically used in fly angling and bait fishing, two hook types (barbed vs. barbless), and two hook locations (lip vs. esophagus/gut) were used in combination to create the different treatment groups (Table 1). A control group (no hook) was also included to quantify background disturbances attributed to transport and laboratory confinement. Following the laboratory acclimation period, individual fish were netted from the holding tank, weighed to the nearest g (W_S), measured (fork length, FL) to the nearest mm and then assigned to one of the seven treatment groups within a single trial in a manner that ensured that fish size (FL) was uniform among treatments. No more than two trials were run in a single holding tank. To avoid inadvertent size bias among treatments, effort was made to ensure an equal distribution of sizes across treatments.

Table 1
Sample size (n), mean and standard error (SE) of fork length (FL) in millimeters (mm) and starting weight (W_S) in grams (g) for bonefish comparing six treatments and the control group. Fork length and starting weight did not vary across treatments (ANOVA $p = 0.999$). The experimental design used two hook types (barbed and barbless), two hook sizes (small #6 and large 1/0), and two hook locations (lip and gut) in six different combinations.

Hook size	Hook type	Hook location	n	FL (mm)	W_S (g)
Small	Barbed	Lip	13	379.1 (10.9)	759.9 (67.7)
Small	Barbed	Gut	13	382.5 (11.4)	791.1 (76.0)
Small	Barbless	Lip	13	377.5 (13.6)	752.8 (85.1)
Small	Barbless	Gut	13	379.2 (12.0)	759.5 (79.4)
Large	Barbed	Lip	12	377.2 (7.16)	741.9 (46.9)
Large	Barbed	Gut	13	381.6 (11.1)	750.5 (80.2)
	All treatments		77	379.5 (8.87)	759.5 (29.4)
	Control		13	374.5 (8.87)	744.5 (57.4)
	All fish		90	378.8 (4.01)	757.3 (26.3)

After being weighed and measured, forceps were used to insert the hook into each fish at one of the two locations; for the "lip" treatment, hooks were inserted through the tissues of the oral cavity where the maxilla and dentary adjoin dorsally from the articular. For the "gut" treatments, hooks were inserted dorsally into the soft palate, posterior to the bony crushing plates that bonefish use for feeding. In a typical angling event in the wild, exact hook location in the oral cavity is presumably highly random. The "lip" treatment was designed to generally represent a hook set made by an angler immediately after a first strike by the fish, and the "gut" treatment represents a delayed hook set by an angler after one or many strikes by the fish. The results based on these experimental procedures should be interpreted as a generalization of how hook location (i.e., roughly "lip" or "gut") may impact hook retention.

To allow observers to determine whether a hook had been lost during the trial (and to replicate conditions that may arise during angling when a fishing line breaks), approximately 40 cm of colored monofilament fishing line was tied to each hook, and left trailing from the mouth of the fish. In addition, an external t-bar anchor tag, color-coded by treatment, was inserted into the dorsal musculature on either the left or right side of each fish, thus allowing the visual assignment of an individual fish to a specific treatment group according to color of the anchor tag. Fish in the control group received identical handling and external tagging procedures, but did not receive a hook. Following the weighing and tagging procedure, two trials of seven fish each (six treatment groups and a control) were held in a common aerated circular holding tank where they were observed daily for 14 days. Individual fish were identified to trial by the position (left or right) of the color-coded anchor tag.

Once per day all bonefish in the holding tank were observed from a distance (without the use of netting or capture) to document mortality, as well as the presence/absence of a hook in a fish (evidenced by the presence/absence of line trailing from the mouth of the fish). Bonefish were also fed queen conch (*Strombus gigas*) offal *ad libitum* once per day during this observation period. At the conclusion of the 14-day observation period, individual bonefish were removed from the tank, the presence/absence of the hook was confirmed by visual inspection of the oral cavity, final weight (W_E) in grams was recorded, and the fish was returned to the sea. Individual fish were not used in more than one trial throughout the experiment.

2.3. Analysis

The fork length (FL) and starting weight (W_S) of fish was compared across treatment groups using a one-way analysis of variance (ANOVA). For each fish it was determined whether the hook was expelled or retained, and the number of days to hook expulsion for individuals that expelled hooks was tabulated. A Fisher's exact test (Sokal and Rohlf, 1994) was used to assess the effect of hook type, size, or location on whether a hook was expelled or retained. Kaplan–Meier survival analysis (using a Mantel–Cox log rank test) was used to compare the time to hook loss by hook type, size and location. Proportional weight change (W_Δ) was calculated as $(W_E - W_S)/W_S$ for all individuals as an indication of the effect of hooking on food consumption rates. To determine if the presence of a hook impacted food consumption, analysis of variance (following arcsin transformation to account for proportion data) was used to compare weight change (W_Δ) between the control group and all treatment groups combined. An ANOVA was also used to assess differences in W_Δ among treatment types (hook location, type and size). The presence or absence of a hook during the trial would be expected to affect feeding ability; therefore we tested for a correlation between the duration of hook retention and W_Δ for individual fish. Mortality rates for each treatment group were also calculated.

3. Results

There were no differences across treatment groups in either fork length ($F = 0.061$; $df = 6{,}83$; $p = 0.999$) or W_S ($F = 0.052$; $df = 6{,}83$; $p = 0.999$; Table 1). Fork length and W_S were highly correlated ($r = 0.950$, $p < 0.001$), indicating that there was no size or condition bias among treatment groups or the control group. There was no mortality observed for any treatment group throughout the study. A single bonefish that was lip-hooked with a large, barbed hook was removed from analysis due to an unrecoverable error in a weight measurement.

3.1. Barbed vs. barbless hooks

Fish hooked with large hooks were pooled with fish hooked with small hooks for comparisons between barbed and barbless treatments because no large barbless hooks were used in this study. In fish that were hooked in the lip, 68% of barbed hooks were expelled within 14 days compared to 69% of barbless hooks (Fisher's exact test, $p = 1.000$). Similarly, in fish that were hooked in the gut, 23% of barbed hooks were expelled while 31% of barbless hooks were expelled (Fisher's exact test; $p = 0.704$; Table 2). Both barbed and barbless hooks located in the lip were expelled in approximately 5 days (Chi-square = 0.266, $df = 1$, $p = 0.606$). Among gut-hooked fish, barbless hooks were expelled in approximately 2 days, while barbed hooks were expelled in approximately 9 days (Chi-square = 6.104, $df = 1$, $p = 0.013$; Fig. 1).

Table 2
Hook retention results during 14-day monitoring period for bonefish hooked with barbed hooks compared to bonefish hooked with barbless hooks. Statistical significance for hook expulsion/retention counts was tested with Fisher's exact test ($df = 1$) while significance for the number days to hook expulsion was tested by Kaplan–Meier survival analysis (using a Mantel–Cox log rank test).

Hook location	Hook type	Hooks expelled	*p*-Value	Mean days to expulsion (SE)	*p*-Value
Lip	Barbed	17/25 (68%)	1.000	5.1 (0.8)	0.606
	Barbless	9/13 (69%)		5.6 (1.0)	
Gut	Barbed	6/26 (23%)	0.704	9.0 (2.3)	0.013
	Barbless	4/13 (31%)		2.3 (0.8)	

3.2. Lip-hooked vs. gut-hooked

Overall, hooks in the lip tended to be expelled 2.6 times more frequently than hooks in the gut (Table 3). Regardless of hook size, barbed hooks located in the lip were expelled 17 out of 25 times while barbed hooks located in the gut were only expelled 6 out of 26 times (Fisher's exact test, $p = 0.002$). Similarly, barbless hooks located in the lip were expelled 9 out of 13 times while barbless hooks located in the gut were only expelled 4 out of 13 times (Fisher's exact test, $p = 0.115$). In general, lip-hooked fish tended to expel their hooks sooner than gut-hooked fish, but only small barbless hooks were statistically significant. Fish hooked in the gut with small barbless hooks expelled their hooks in approximately 2

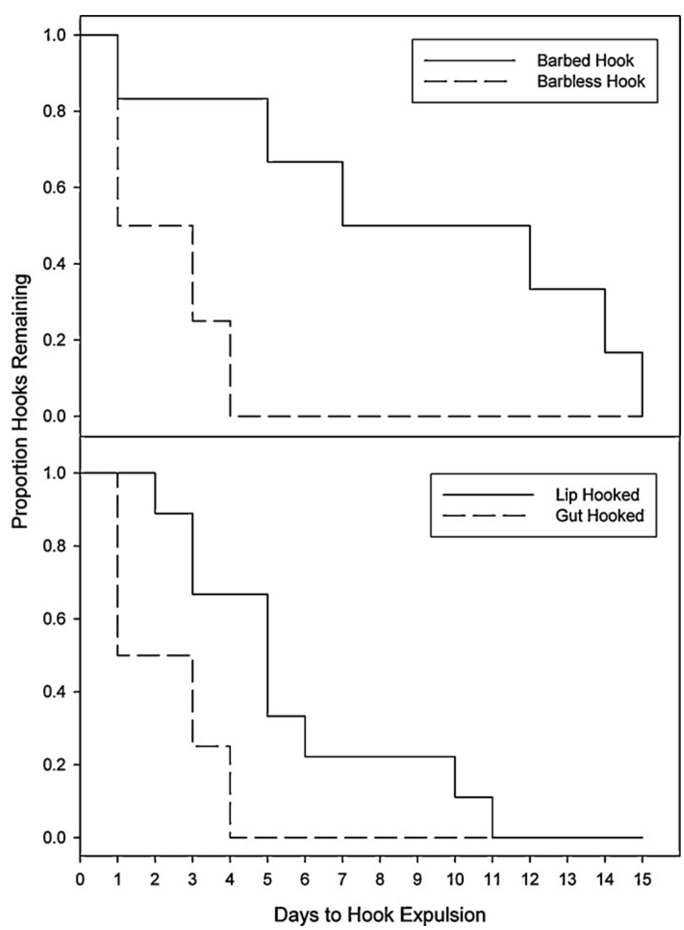

Fig. 1. Kaplan–Meier survival functions for bonefish based on daily observations for hook presence/absence recorded over a 14-day monitoring period. The top panel, comparing hook retention probabilities for barbed and barbless hooks located in the gut. The bottom panel compares hook retention probabilities for lip-hooked and gut-hooked bonefish hooked with small barbless hooks.

Table 3
Hook retention results during 14-day monitoring period for bonefish hooked in the lip compared to bonefish hooked in the gut. Statistical significance for hook expulsion/retention counts was tested with Fisher's exact test ($df = 1$) while significance for the number days to hook expulsion was tested by Kaplan–Meier survival analysis (using a Mantel–Cox log rank test).

Hook size and type	Hook location	Hooks expelled	*p*-Value	Mean days to expulsion (SE)	*p*-Value
Small, barbed	Lip	9/13 (69%)	0.047	6.0 (1.3)	0.606
	Gut	3/13 (23%)		8.0 (2.1)	
Large, barbed	Lip	8/12 (67%)	0.047	4.1 (0.8)	0.118
	Gut	3/13 (23%)		10.0 (4.5)	
Small, barbless	Lip	9/13 (69%)	0.115	5.6 (1.0)	0.016
	Gut	4/13 (31%)		2.3 (0.8)	

days compared to lip-hooked fish that expelled their hooks in over 5 days (Chi-square = 5.846, $df = 1$, $p = 0.016$; Fig. 1).

3.3. Small vs. large hooks

For both small and large hooks, lip-hooked fish expelled their hooks about 68% of the time compared to gut hook fished, which expelled their hooks about 23% of the time (Table 4). Within both lip-hooked and gut-hooked fish, there was no difference in the number of hooks expelled relative to hook size (Chi-square = 0.000, $df = 1$, $p = 1.000$). Among lip-hooked fish, small hooks were expelled in approximately 6 days compared to large hooks, which were expelled in approximately 4 days, although differences were not statistically significant (Chi-square = 0.791, $df = 1$, $p = 0.374$). Among gut-hooked fish, small hooks were expelled in approximately 5 days while large hooks were expelled in about 10 days (Chi-square = 1.182, $df = 1$, $p = 0.277$).

3.4. Weight change

There were no significant differences in weight change (W_{Δ}) between hooked fish and the control group ($F = 0.111$, $p = 0.739$; Fig. 2). Within hooked fish, there were no significant differences in weight change among fish that expelled their hooks and fish that retained hooks ($F = 0.502$, $p = 0.481$), although the amount of weight lost by bonefish that retained their hooks was more than either the expelled or control groups (Table 5). Among fish that were hooked in the lip with large, barbed hooks, fish that retained hooks lost significantly more weight than fish that expelled hooks ($F = 15.040$; $p = 0.003$). There was no difference in weight change between fish that retained hooks and those that expelled hooks within any of the other treatment groups. There was no significant correlation between W_{Δ} and the number of days to loss of the hook among fish that expelled their hook ($r = -0.140$, $p = 0.417$).

Table 4
Hook retention results during 14-day monitoring period for bonefish hooked with large hooks compared to bonefish hooked with small hooks. Statistical significance for hook expulsion/retention counts was tested with Fisher's exact test ($df = 1$) while significance for the number days to hook expulsion was tested by Kaplan–Meier survival analysis (using a Mantel–Cox log rank test).

Hook location	Hook size	Hooks expelled	*p*-Value	Mean days to expulsion (SE)	*p*-Value
Lip	Small	9/26 (69%)	1.000	5.8 (0.8)	0.191
	Large	8/12 (67%)		4.1 (0.8)	
Gut	Small	7/26 (27%)	1.000	4.7 (1.5)	0.102
	Large	3/13 (23%)		10.0 (4.5)	

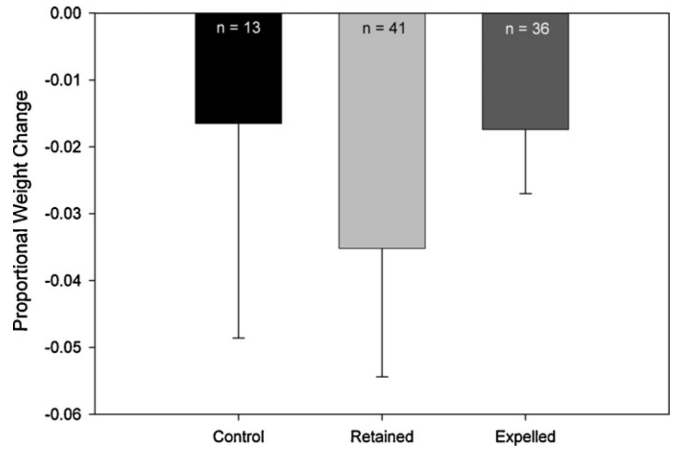

Fig. 2. Comparison of proportional weight loss among bonefish that expelled hooks, retained hooks, and the control group.

4. Discussion

In many recreational fisheries, anglers with a strong conservation ethic commonly practice catch-and-release as a means to ensure the survival of the fish they catch while supporting the long-term viability of the population (Arlinghaus et al., 2007; Policansky, 2002). There is a growing body of evidence that post-release survival of an angled fish is dependent on a combination of gear type and angler behavior (Arlinghaus et al., 2007; Cooke and Suski, 2005; Fobert et al., 2009). In bonefish, the magnitude of physiological disturbance caused by an angling event is directly related to fight time and air exposure (Cooke et al., 2008; Suski et al., 2007). Such physiological disturbances can lead to losses in equilibrium (Cooke and Philipp, 2004), which has been shown to lead to increased levels of post-release predation (Danylchuk et al., 2007b). The ability of an angler to land a fish quickly, rapidly remove a hook, and immediately release the fish should, therefore, increase the likelihood of post-release survival. Additionally, fish angled in high-risk, predator-rich environments are more vulnerable to predation as they recover from the physiological trauma of the angling event (Danylchuk et al., 2007b). Where potential predators are abundant, or when a hook is difficult to remove, anglers may choose to cut the line to avoid excessive handling and air exposure to increase the likelihood of post-release survival. Because rapid hook removal will depend largely on the type, size and location of the hook set (as well as the experience and ability of the angler), anglers may select hook sizes and/or types (e.g., barbed or barbless) that facilitate easy hook removal, reduce handling stress, and promote post-release survival.

The current study demonstrated that, over a 14-day monitoring period, hook expulsion in bonefish was relatively common, with 46% of all hooks expelled, regardless of hook type, size or location. Neither hook type (barbed vs. barbless) nor hook size (small vs. large) had any impact on expulsion rates, although small barbed hooks located in the lip were more frequently expelled than small barbed hooks in the gut. The number of days required for a bonefish to expel a hook was highly variable (2–10 days) showing no overall significant pattern across hook sizes, hook types or hook locations. Among gut-hooked fish, however, barbless hooks were expelled 3.9 times sooner than barbed hooks. Barbed hooks have previously been shown to influence an angler's ability to remove a hook from a fish in a timely manner resulting in additional handling and/or air exposure (see Bartholomew and Bohnsack, 2005) as well as additional tissue damage relative to barbless hooks (Muoneke and Childress, 1994). Therefore, despite the fact that expulsion rates were influenced by the presence of a barb in only

Table 5
Comparison of proportional weight change (W_{Δ}) between fish that expelled hooks and those that retained hooks throughout the 14-day observation period for each treatment combination. Significance values for a one-way ANOVA are given.

Hook size	Hook type	Hook location	W_{Δ}		*p*
			Expelled hooks	Retained hooks	
	Control		0.017 (*n* = 13)		
	All treatments		−0.017 (*n* = 36)	−0.034 (*n* = 41)	0.481
Small	Barbed	Lip	−0.029 (*n* = 9)	−0.047 (*n* = 4)	0.695
Small	Barbed	Gut	−0.060 (*n* = 3)	−0.066 (*n* = 10)	0.902
Small	Barbless	Lip	−0.017 (*n* = 9)	−0.054 (*n* = 4)	0.371
Small	Barbless	Gut	0.027 (*n* = 4)	−0.034 (*n* = 9)	0.082
Large	Barbed	Lip	−0.006 (*n* = 8)	−0.070 (*n* = 4)	0.003
Large	Barbed	Gut	−0.031 (*n* = 3)	0.025 (*n* = 10)	0.700

a few treatments in the current study, barbed hooks may have negative impacts on post-release survival for bonefish in cases where anglers attempt to remove the hook, increasing stress and/or trauma for released fish. DuBois and Pleski (2007) found expulsion rates between barbed and barbless hooks to be similar in deeply hooked brook trout (*Salvelinus fontinalis*), and that 20% of fish expelled hooks during a six-week observation period. Tsuboi et al. (2006) reported high survival rates and expulsion rates of 33% over three months using deeply hooked barbed hooks in white-spotted charr (*Salvelinus leucomaenis*). Our study showed similar expulsion rates for bonefish hooked in the gut (23–31%), albeit over a significantly shorter duration (14 days). Schill (1996) reported higher expulsion rates (60–74% over approximately 30 days) for gut-hooked rainbow trout (*Oncorhynchus mykiss*), although Schisler and Bergersen (1996) reported expulsion rates of 24% over three weeks for deeply hooked rainbow trout. These comparison studies used methods that required removal of hooks from lip-hooked fish prior to release, precluding comparisons of expulsion rates among lip-hooked bonefish in our study. Our finding that lip-hooked bonefish expelled their hooks more rapidly than gut-hooked fish for several treatments is likely due to a fish's ability to manipulate hooks in the oral cavity through jaw movements or through contact with substrate. In fact, some individual bonefish were observed "rubbing" against the bottom of holding tanks during this study, and similar behaviors ("flashing") have been observed by several of the authors in the wild. The ability of a bonefish to use its pharyngeal plates to manipulate a deep hook may explain why deeply hooked bonefish expelled small barbless hooks more quickly, although less frequently, than identical hooks located in the lip. Over time, bonefish are likely to expel hooks regardless of type, size or location, and post-release mortality does not appear to be attributable to the presence or absence of a hook. Rather, physiological impacts of the angling event (Suski et al., 2007) and nearby predators (Danylchuk et al., 2007a) likely drive post-release mortality in this species.

Bonefish feed regularly in shallow coastal areas in water depths less than 0.3 m (Crabtree et al., 1998), making forays into feeding areas on an incoming tide (Colton and Alevizon, 1983; Engstrom and Lucenti, 1984). This diurnal foraging pattern restricts feeding opportunities to times of the day when the flood tide allows access to shallow habitats that support prey items (Engstrom, 1984). In bonefish that have been angled and released with a hook lodged in their oral cavity, the hook may be an obstruction that limits feeding in these prey-rich habitats. We hypothesized that the presence of a hook could negatively impact feeding ability, predicting that the longer a hook remained in the fish, the more feeding would be impacted and the greater the weight change. However, there was no correlation between the number of days a hook remained in the fish and short-term weight change, nor did any single treatment group show weight change significantly different than the control group, indicating that the presence of a hook did not appear to impact the feeding capabilities of bonefish under the conditions of this study. Further, there was no relationship between weight loss and hook type, size, nor location, indicating that the presence of a hook in a released bonefish may not obstruct feeding, and is likely not a factor in post-release survival. No mortality was observed during this study, providing additional evidence that post-release survival is not significantly affected by the presence of a hook. The 14-day observation period used in this study was sufficient to detect post-release mortality in bonefish (Danylchuk et al., 2007a), exceeds observation periods used in similar studies evaluating post-release mortality in marine fishes (see Grover et al., 2002), and provided sufficient time to detect sub-lethal effects of hooking (i.e., indicators of stress) that may be indicative of impending mortality. Our results suggest that leaving a hook in an angled bonefish does not negatively affect growth or survival, and that there is a strong likelihood that a hook will be eventually expelled with few ill effects to the fish. To facilitate clear comparisons among treatment groups, our study included treatments restricted to two specific hooking locations (i.e., "lip" and "gut") that do not represent the full array of random hooking locations typically encountered in a wild fishery (i.e., gills, organs). Although several other studies have indicated that the physiological stresses associated with the overall angling event can influence post-release survival via increased predation (Cooke and Philipp, 2004; Cooke et al., 2008; Danylchuk et al., 2007b; Suski et al., 2007), the role hook retention plays in contributing to such impacts still remains to be tested.

Results from this study have a number of implications for recreational anglers targeting bonefish. Anglers striving to maximize the survival of released bonefish should consider both the difficulty of removing imbedded hooks (both potential tissue damage as well as air exposure/handling), coupled with the threat level presented by predators in the area when determining whether to cut the line and release the fish. This study did not examine the influence of hooking damage nor post-release predation rates in fish that retained hooks, although understanding hook-related pathology and predation would strengthen recommendations to anglers on whether to remove the hook. Although there was no indication barbless hooks increase the likelihood of post-release expulsion, barbless hooks will reduce hook removal handling stress (Meka, 2004), and therefore should be preferred by anglers as a way to maximize physiological condition at time of release (Cooke et al., 2001).

Acknowledgements

We would like to thank the Cape Eleuthera Institute for financial and logistical support, as well as students from The Island School (P. Beardsley, A. Graziano, L. Hartwell, S. MacKenzie, and R. Sherman) who participated in this study. C. Haak, S. Kenworthy, J. Searle, and

J. Stokley assisted with field collection. Funding was provided by Bonefish and Tarpon Trust.

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