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Post-release mortality of bonefish, *Albula vulpes*, exposed to different handling practices during catch-and-release angling in Eleuthera, The Bahamas

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Abstract Bonefish, *Albula* spp., are popular sportfish that inhabit shallow nearshore environments in tropical and subtropical seas. Although catch and release is a common voluntary practice for anglers seeking bonefish, the post-release fate of bonefish is poorly understood. Gastrically implanted acoustic transmitters were used to assess the short-term (< 48 h) and long-term (> 48 h) post-release mortality of bonefish, *Albula vulpes* (Linnaeus), in Eleuthera, The Bahamas, subjected to gentle handling (quick retrieval, 0–15 s of air exposure and brief handling time) or rough handling (longer retrieval, 30–60 s of air exposure and extended handling time). Of the 12 fish captured and released, one was preyed upon by two lemon sharks, *Negaprion brevirostris* (Poey), within the first hour post-release, and this fish was handled roughly. The transmitter from another bonefish was found on the substratum 2 days post-release near the site at which the fish was originally caught. Of the remaining 10 fish, all were tracked and alive for at least 13 days and up to 24 days, suggesting that the negative impacts of catch-and-release angling that lead to mortality for bonefish likely occur within minutes post-release.

KEYWORDS: bonefish, catch-and-release angling, handling, mortality, The Bahamas.

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Introduction

Bonefish, *Albula* spp., are a group of fishes that inhabit shallow tropical and subtropical marine environments worldwide (Alexander 1961). Angling for bonefish has become a popular recreational activity of important economic value. For example, the recreational bonefishing industry in Florida is estimated to generate several billion dollars annually (Humston 2001), making the economic value of an individual adult bonefish in this region potentially high. The relative value of bonefish to small nations, such as The Bahamas, can be much greater, because the revenues generated through bonefishing-related tourism can form the economic basis of entire local communities.

The sustainability of a recreational bonefishing industry is contingent upon the maintenance of abundant and healthy stocks. In the case of bonefish, most recreational anglers voluntarily practice catch-and-release in an effort to ensure that local populations do not become depleted (Policansky 2002). This common form of fisheries conservation operates under the assumption that the impacts of angling do not negatively affect fish survival (Muoneke & Childress 1994; Cooke, Schreer, Dunmall & Philipp 2002; Cooke & Suski 2005). If the survival of released bonefish is compromised, then catch-and-release angling as a conservation tool could generate a false sense of security (Cooke & Philipp 2004; Humston, Ault, Larkin & Jiangang 2005).

In various fishes, physical stresses imposed through angling can disrupt natural physiological processes and behaviours that may ultimately affect survival. Involuntary restraint, prolonged handling and air exposure resulting from angling can modify cardiovascular and respiratory activity (Cooke, Dunmall, Schreer & Philipp 2001) as well as alter white muscle and blood biochemistry (Ferguson & Tufts 1992; Kieffer 2000), leading to swimming impairment, disorientation and loss of equilibrium (Ferguson & Tufts 1992; Kieffer 2000; Cooke *et al.* 2002; Cooke & Philipp 2004). If recovery from such angling-induced stresses is slow and if fish are released prematurely, the impaired behaviours could affect short-term survival, particularly where predators are abundant.

The role of catch-and-release in conserving bonefish populations has received limited attention (Crabtree, Snodgrass & Harnden 1998; Cooke & Philipp 2004). In an earlier study, Crabtree *et al.* (1998) held bonefish in a small pond and repeatedly angled them over several years. Although mortality was low (4%), the restricted nature of the pond environment limited the study's relevance to natural environments, especially those containing predators. More recently, Cooke & Philipp (2004) evaluated the short-term survival (24–48 h) of bonefish following angling events. In a site with low predator abundance, no mortality of bonefish occurred despite long angling duration, extended air exposure and frequent loss of equilibrium among landed fish. Conversely, at a site with higher predator abundance, 39% of released bonefish were preyed upon despite having been landed more rapidly and exposed to air for shorter durations than bonefish released at the low-predator site (Cooke & Philipp 2004). Although these results suggest that post-release mortality of bonefish can be high, differences in the treatment of bonefish between areas of high and low predator abundance did not allow for a clear evaluation of the role of different handling practices on survival.

The purpose of this study was to determine the short-term (<48 h) and long-term (>48 h) fate of bonefish that were angled and then released under various angling and handling practices. Specifically, it was hypothesised that bonefish subjected to relatively intense angling events would have a greater chance of both short-term and long-term post-release mortality. Acoustic telemetry was used to locate bonefish post-release, which also allowed examination of the movements of bonefish in nearshore flats, an aspect of their ecology that has only received limited attention (e.g. Colton & Alevizon 1983; Humston *et al.* 2005).

Materials and methods

Study site

This study was conducted along a 4-km stretch of the north coast of Cape Eleuthera, Eleuthera, The Bahamas (N 24 50 05 and W 76 20 32; Fig. 1). The shoreline along the north coast of Cape Eleuthera is composed of small, sandy bays and sharp calcium carbonate outcroppings. Two small tidal flats systems (<0.3 km^2) known as Kemp's Creek and Broad Creek occur along the north coast of Cape Eleuthera. The creeks are characterised by a mosaic of sandy beach and turtle grass, *Thalassia testudium* (Banks ex Konig), beds surrounded by tracts of red mangroves, *Rhizophora mangle* (Linnaeus).

Preliminary genetic analyses on the bonefish used in this study and in the study conducted by Cooke & Philipp (2004) indicated that all specimens were *Albula vulpes* (Linnaeus). Other than bonefish, common fish species within the creeks include lemon shark, *Negaprion brevirostris* (Poey), great barracuda, *Sphyraena barracuda* (Edwards), checkered puffer, *Sphoeroides testudineus* (Linnaeus), redfin needlefish, *Strongylura notata notata* (Poey), yellowfin mojarra, *Gerres cinereus*

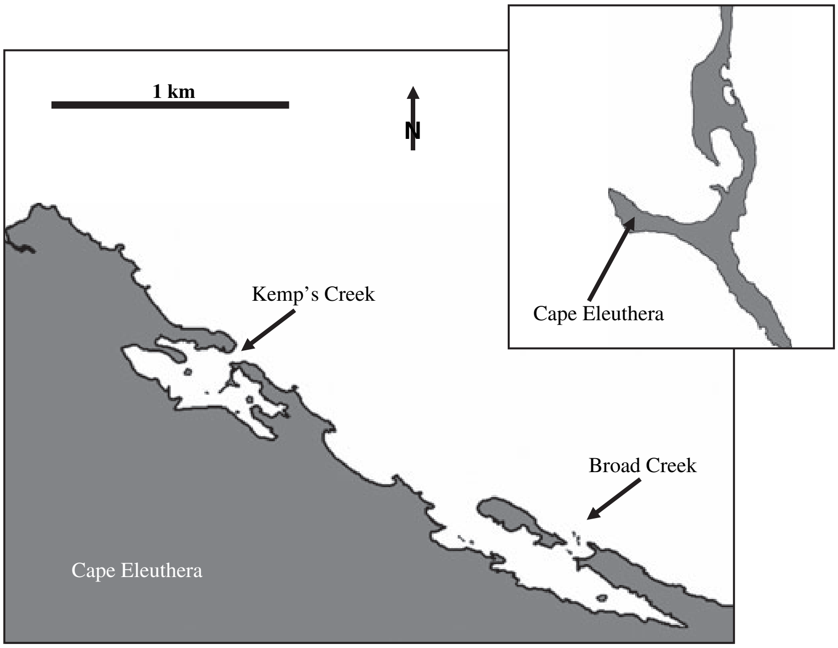

Figure 1. Study area along the north coast of Cape Eleuthera, Eleuthera, The Bahamas, showing the location of Kemp's Creek and Broad Creek (larger image).

(Walbaum) and bigeye mojarra, *Eucinostomus havana* (Nichols) (A.J. Danylchuk, unpublished data). Of these, only lemon sharks and barracuda greater than 50 cm are considered to be potential predators of bonefish (see Cooke & Philipp 2004). The abundance of lemon sharks in Broad Creek is somewhat higher than in Kemp's Creek (0.94 ± 0.35 SE shark h^{-1} vs 0.48 ± 0.13 SE shark h^{-1} respectively), but the abundance of barracuda in both creeks is approximately the same (0.23 ± 0.09 SE barracuda h^{-1} and 0.20 ± 0.11 SE barracuda h^{-1} respectively; A.J. Danylchuk, unpublished data).

Fish collection and ultrasonic telemetry

Fish collection and telemetry were conducted at Kemp's Creek and Broad Creek between 14 October and 14 November 2004. Bonefish were angled using standard fly fishing equipment (seven to nine weight rods and reels, No. 6 barbed flies). A total of 12 fish, equally divided between Kemp's Creek and Broad Creek, were used in this study. Prior to being caught, individual fish were assigned to one of two handling treatments: gentle handling (quick retrieval, 0–15 s of air exposure and brief handling time) or rough handling (longer retrieval, 30–60 s of air exposure and extended handling time). To confirm differences between the two handling treatments, the durations of angling and air exposure were measured to the nearest 15 s. When landed, each fish was assessed for the anatomical location of the hook, extent of hook injury and degree of physical abnormalities. Each fish was measured (total length to the nearest cm). Total handling time and water depth at the location of capture were also recorded.

Before release, each bonefish was implanted with an ultrasonic gastric transmitter. The transmitter (V8SC-6L and V8SC-2L continuous pinger, 3.5 g in air, 33 × 9 mm; Vemco Inc., Shad Bay, Canada) was inserted into the stomach of the fish through a smooth plastic tube and plunger that was gently inserted into the oesophagus. The entire procedure took less than 30 s and was conducted while the fish was entirely submerged. Gastric transmitters are commonly used for telemetry in fish because they are relatively noninvasive and because they minimise additional handling disturbance (Bridger & Booth 2003). As a result, these transmitters are particularly useful for studies of catch-and-release angling (Cooke *et al.* 2002; Cooke & Philipp 2004). Transmitters were designed to produce a continual and individually recognisable ultrasonic ping for 30–40 days following activation.

Following release, transmitter-implanted fish were located using a manual receiver (USR-5W; Sonotronics Inc., Tucson, AZ, USA) with a directional hydrophone. Fish were tracked by boat and by wading. Fish were continually tracked for up to 1 h post-release, and then at irregular intervals at predetermined locations distributed throughout the study area. Given the life expectancy of the transmitters, monitoring continued for a minimum of 3 weeks post-implantation. If a transmitter continued to be detected beyond 3 weeks post-implantation, monitoring was extended for 1 week past the last date the transmitter was heard.

Data analysis

Parametric statistics (t-tests, one-way ANOVA) were used to test the significance of differences in continuous variables among the two study sites, the two handling treatments, and the different handling parameters. Nonparametric statistics (Mann–Whitney U-test) were used when assumptions of a linear model could not be met. Linear regression was used to examine the relationship between continuous treatment variables. Statistical analyses were performed using Statistica '99 for the PC (StatSoft Inc., Tulsa, OK, USA).

Results

There were no significant differences in the duration of the angling event ($t = 0.54$, $P = 0.60$), air exposure ($t = 2.02$, $P = 0.11$) or total handling time ($t = 0.84$, $P = 0.42$) between fish captured at Kemp's and Broad Creeks (Table 1). Body size of bonefish and water depth at the location of capture also were not significantly different between creeks ($t = 0.72$, $P = 0.36$ and $t = 1.36$, $P = 0.21$ respectively). For both creeks combined, duration of the angling event was not related to body size ($R^2 = 0.025$, $P = 0.62$). Hooking locations were predominantly in the lower (58%) or upper (33%) lip (located at or near the corner of the mouth); only one fish (8%) was hooked in the tongue. Half of the fish bled from the hooking location following removal of the fly, and the incidence of bleeding was not related to the duration of the angling event ($Z = -1.76$, $P = 0.078$).

Of the 12 bonefish captured, half were treated gently (167 ± 26 s SE angling time, 0–15 s of air exposure and 385 ± 70 s SE total handling time), and half were treated roughly (235 ± 31 s SE angling time, 30–60 s of air exposure and 592 ± 49 s SE total handling time).

Table 1. Size and handling metrics of bonefish collected from Kemp's Creek and Broad Creek, Eleuthera, The Bahamas, October 2004

	Broad Creek	Kemp's Creek
Total length (cm)	48 ± 9	47 ± 5
Water depth at capture (cm)	25 ± 14	34 ± 9
Duration of angling (s)	187 ± 74	212 ± 83
Air exposure (s)	13 ± 24	37 ± 18
Total handling time (s)	445 ± 161	533 ± 198

Values are mean ± 1 SD; $n = 6$ for each creek.

No predation attempts were made while fish were on the line, and only one of the roughly handled fish (from Kemp's Creek; 300 s of angling time, 60 s of air exposure and 750 s total handling time) was visibly preyed upon after release. Following release, this bonefish was initially disorientated and swam slowly into extremely shallow water before it turned and rejoined the school from which it was caught. Once in the school, this fish was subsequently attacked and killed by two lemon sharks (both approx. 1 m TL) 3 min after release.

The position of a second but gently handled (147 s of angling time, 15 s of air exposure and 210 s total handling time) bonefish remained stationary for 2 days post-release. The transmitter was subsequently recovered resting on the substrate approximately 25 m to the north of the mouth of Kemp's Creek, no longer inside the bonefish in which it was implanted. It could not be determined whether the transmitter was regurgitated by the bonefish after its release, or whether the transmitter was excreted by a predator at this location after it had consumed the bonefish elsewhere.

Of the 10 remaining transmitter-implanted bonefish, those caught from Kemp's Creek were located for an average of 15 days post-release (range 13–21 days) while those caught from Broad Creek were located for an average of 16 days (range 13–24 days). There was no significant difference between creeks in the duration of time that fish were tracked ($t = -0.36$, $P = 0.73$).

Independent of handling treatment, 70% of fish caught-and-released moved between Kemp's Creek and Broad Creek post-release. Interestingly, all fish released in Kemp's Creek ($n = 4$ after the loss of the first two fish implanted with transmitters) were later located in Broad Creek, either the same day ($n = 2$), 1 day ($n = 1$) or 2 days ($n = 1$) post-release. Two of these fish were located only once again in Kemp's Creek, while the other two were located only in Broad Creek. Of the six fish caught in Broad Creek, three were located in Kemp's Creek either 2, 11 or 12 days post-release, while the other three bonefish were located only in Broad Creek. Overall, the movement of bonefish between study sites was not associated with treatment (number of gently handled fish that moved = 3, number of roughly handled fish that moved = 4).

Discussion

The results of this study suggest that if bonefish are able to avoid predation for the first few minutes following release, then delayed mortality is relatively unimportant, regardless of handling treatment. The abundance of predators can, thus, play a major role in the susceptibility of post-release mortality for caught-and-released bonefish (Cooke & Philipp 2004; this study). For instance, the abundance of sharks at the two study sites off Cape Eleuthera (average abundance of 0.71 ± 0.19 SE shark h^{-1} for Kemp's and Broad Creeks) is intermediate to the shark abundances reported by Cooke & Philipp (2004) for San Salvador (0.059 shark h^{-1}) and Deep Water Cay (1.46 sharks h^{-1}); the post-release mortality of bonefish in this study (8%) was also intermediate to the post-release mortality of bonefish at San Salvador (0%) and Deep Water Cay (39%). The potential association between shark abundance and post-release mortality would imply that anglers' decisions regarding fishing location could influence the effectiveness of catch-and-release angling as a conservation tool. In this study, differences in the short-term post-release mortality between Broad and Kemp's Creeks (0% and 8% respectively) were not consistent with differences in shark abundance (Broad Creek 0.94 ± 0.35 SE shark h^{-1} vs Kemp's Creek 0.48 ± 0.13 SE shark h^{-1}); however, predation on a single bonefish limits inferences. The results suggest that at intermediate predator densities, other factors, such as those related to the angling event itself, may play a greater role in affecting the incidence of post-release mortality of bonefish.

Handling practices can influence the susceptibility of fishes to predation post-release (reviewed in Cooke & Suski 2005). In this study, the only fish actually observed to be preyed upon was one that was treated roughly during handling. Rough handling could have resulted in loss of equilibrium, causing the disorientation and slow swimming that was observed for this individual immediately following release. In turn, despite returning to the school from which it was caught, this fish was singled out and preyed upon after only 3 min likely because of behavioural or physiological cues (e.g. excretion of stress hormones) detectable by predators in the vicinity. Although the exact fate of another bonefish whose transmitter was recovered 2 days post-release is not known, it is plausible that this fish was preyed upon by a shark or barracuda. This fish was caught at Kemp's Creek, the same site where the roughly handled bonefish was preyed upon by sharks, yet handled gently. None of the remaining 10 fish suffered predation, despite rough handling and bleeding in half of these fish. This suggests that site-specific differences at the location of release, such as the physical properties of the flats themselves, may also play a role in the susceptibility of bonefish to post-release predation.

Variation in the habitat types associated with flats may influence the ability of released bonefish to evade predators. For instance, Humston *et al.* (2005) found that bonefish in the upper Florida Keys tended to avoid deep channels and suggested that this could be a strategy to avoid large predators. The sites off Cape Eleuthera used in this study have no deep channels adjacent to shallow water; therefore, predators inhabiting flats dominated by shallow water might pose an equal, if not greater, threat to bonefish. Other physical features associated with flats, such as red mangroves and their network of prop roots, might offer bonefish refuge from predators following release.

Tides and thermal regimes associated with the physical properties of flats can influence the behaviour and movement of bonefish (Colton & Alevizon 1983; Crabtree *et al.* 1998; Humston *et al.* 2005) and, in turn, may influence the susceptibility of bonefish to predation following catch-and-release. Both Colton & Alevizon (1983) and Humston *et al.* (2005) found that the movement of transmitter-implanted bonefish in near-shore flats was more or less synchronous with the ebbing and flooding tides (moving into deeper water with ebbing tides and moving into shallow flats on flooding tides) and suggested that movements into deeper water were attributed to the avoidance of high water temperatures associated with shallow flats. High water temperatures could be physiologically taxing to bonefish especially following exertion, as is true for other fish species (e.g. Wilkie, Brobbel, Davidson, Forsyth & Tufts 1997; Cooke, Ostrand, Bunt, Schreer, Wahl & Philipp 2003; Meka & McCormick 2004). The need to avoid the warm water of shallow flats and the need to remain in shallow water to find refuge from predation could operate as opposing forces influencing bonefish movement patterns. This may be especially true during high tides in warm summer months when water temperature in shallow flats inhabited by bonefish can exceed 35 °C (A.J. Danylchuk, unpublished data).

Knowing how the different components of catch-and-release angling contribute to post-release survival is critical to the development of scientifically based catch-and-release guidelines and regulations for bonefish (Cooke & Philipp 2004; Cooke & Suski 2005). Also critical is how the behaviour and movement of bonefish are influenced by the physical characteristics of the flats themselves, and whether site-specific characteristics of flats can influence the post-release mortality of caught-and-released bonefish. Most studies examining the movement of bonefish have focused on stocks in the Florida Keys, USA (Crabtree *et al.* 1998; Humston 2001; Humston *et al.* 2005), likely because of their accessibility from the mainland. However, conducting comparative studies on the catch-and-release mortality and movements of bonefish at numerous locations, potentially involving separate species of bonefish that occur within and among regions (Colborn, Crabtree, Shaklee, Pfeiler & Bowen 2001), may help in the development of generalised guidelines for enhancing the sustainability of bonefish stocks and the tourist-based economies that rely on them.

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References

Alexander E.C. (1961) *A Contribution to the Life History, Biology and Geographical Distribution of Bonefish, Albula vulpes* (Linnaeus). Dana-Report No. 53. Copenhagen: Carlsberg Foundation, 55 pp.

Bridger C.J. & Booth R.K. (2003) The effects of biotelemetry transmitter presence and attachment procedures on fish physiology and behavior. *Reviews in Fisheries Science* **11,** 13–34.

Colborn J., Crabtree R.E., Shaklee J.B., Pfeiler E. & Bowen B.W. (2001) The evolutionary enigma of bonefishes (*Albula* spp.): cryptic species and ancient separations in a globally distributed shorefish. *Evolution* **55,** 807–820.

Colton D.E. & Alevizon W.S. (1983) Movement patterns of bonefish, *Albula vulpes*, in Bahamian waters. *Fisheries Bulletin* **81,** 148–154.

Cooke S.J. & Philipp D.P. (2004) Behavior and mortality of caught-and-released bonefish (*Albula* spp.) in Bahamian waters with implications for a sustainable recreational fishery. *Biological Conservation* **118,** 599–607.

Cooke S.J. & Suski C.D. (2005) Do we need species-specific guidelines for catch-and-release recreational angling to conserve diverse fishery resources? *Biodiversity and Conservation* **14,** 1195–1209.

Cooke S.J., Dunmall K., Schreer J.F. & Philipp D.P. (2001) The influence of terminal tackle on physical injury, handling time and cardiac disturbance of rock bass. *North American Journal of Fisheries Management* **21,** 265–274.

Cooke S.J., Schreer J.F., Dunmall K.M. & Philipp D.P. (2002) Strategies for quantifying sublethal effects of marine catch-and-release angling – insights from novel freshwater applications. *American Fisheries Society Symposium* **30,** 121–134.

Cooke S.J., Ostrand K.G., Bunt C., Schreer J.F., Wahl D.H. & Philipp D.P. (2003) Cardiovascular responses of largemouth bass to exhaustive exercise and brief air exposure over a range of water temperatures. *Transactions of the American Fisheries Society* **132,** 1154–1165.

Crabtree R.E., Snodgrass D. & Harnden C. (1998) Survival rates of bonefish, *Albula vulpes*, caught on hook-and-line gear and released based on capture and release of captive bonefish in a pond in the Florida Keys. In: *Investigations into Nearshore and Estuarine Gamefish Abundance, Ecology and Life History in Florida, Five Year Technical Report to the US Fish and Wildlife Service, Sport Fish Restoration Project F-59*. St Petersburg, FL, USA: Florida Marine Research Institute, pp. 252–254.

Ferguson R.A. & Tufts B.L. (1992) Physiological effects of brief air exposure in exhaustively exercised rainbow trout (*Oncorhynchus mykiss*): implications for "catch and release" fisheries. *Canadian Journal of Fisheries and Aquatic Sciences* **49,** 1157–1162.

Humston R. (2001) *Development of Movement Models to Assess the Spatial Dynamics of Fish Populations*. Doctoral dissertation, Miami, FL, USA: Rosenstiel School of Marine and Atmospheric Science, University of Miami, 254 pp.

Humston R., Ault J.S., Larkin M.F. & Jiangang L. (2005) Movements and site fidelity of the bonefish *Albula vulpes* in the northern Florida Keys determined by acoustic telemetry. *Marine Ecology Progress Series* **291,** 237–248.

Kieffer J.D. (2000) Limits to exhaustive exercise in fish. *Comparative Biochemistry and Physiology* **126A,** 161–179.

Meka J.M. & McCormick S.D. (2004) Physiological response of wild rainbow trout to angling: impact of angling duration, fish size, body condition, and temperature. *Fisheries Research* **72,** 311–322.

Muoneke R.A. & Childress W.M. (1994) Hooking mortality: a review for recreational fisheries. *Reviews in Fisheries Science* **2,** 123–156.

Policansky D. (2002) Catch-and release recreational fishing: a historical perspective. In: T.J. Pitcher & C.E. Hollingwoth (eds) *Recreational Fisheries: Ecological, Economic and Social Evaluation*. Cambridge, UK: Blackwell Science Ltd, pp. 74–94.

Wilkie M.P., Brobbel M.A., Davidson K., Forsyth L. & Tufts B.L. (1997) The influence of temperature on the post-exercise physiology and survival of Atlantic salmon (*Salmo salar*). *Canadian Journal of Fisheries and Aquatic Sciences* **54,** 503–511.