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Consequences of catch-and-release angling on the physiological status, injury, and immediate mortality of great barracuda (*Sphyraena barracuda*) in The Bahamas

Amanda C. O'Toole, Andy J. Danylchuk, Cory D. Suski and Steven J. Cooke

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Great barracuda (*Sphyraena barracuda*) are a common marine predatory fish readily captured by anglers (frequently as incidental bycatch while pursuing other gamefish) and are consequently released at high rates. A study was conducted in coastal waters of The Bahamas to evaluate how common angling techniques influence their physiological status, hooking injury, and immediate mortality. Post-angling blood glucose and plasma sodium levels increased with fight-time duration, though lactate levels increased only with longer blood sampling times. Concentrations of plasma chloride and potassium were not influenced by angling duration. We did not observe any differences in injury, bleeding, hook removal, or hooking depth among three types of artificial lure tested. Most fish were hooked in non-critical areas and experienced minimal or no bleeding at the hook site, so immediate mortality upon landing was negligible. Although great barracuda appear to be fairly resilient to physiological stress and injury associated with catch-and-release angling and immediate mortality was insignificant, they typically reside in habitats where post-release predation is possible. As such, efforts should be made to promote careful handling to ensure high rates of survival.

Keywords: angling stress, catch-and-release, great barracuda, injury, physiology.

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A. C. O'Toole and S. J. Cooke: Fish Ecology and Conservation Physiology Laboratory, Department of Biology, Carleton University, Ottawa, ON, Canada K1S 5B6. A. C. O'Toole, A. J. Danylchuk, C. D. Suski, and S. J. Cooke: Flats Ecology and Conservation Program, Cape Eleuthera Institute, PO Box 29, Rock Sound, Eleuthera, The Bahamas. A. J. Danylchuk: Department of Natural Resources Conservation, University of Massachusetts Amherst, Amherst, MA 01003-9285, USA. C. D. Suski: Department of Natural Resources and Environmental Sciences, University of Illinois, Urbana, IL 61801, USA. S. J. Cooke: Institute of Environmental Science, Carleton University, Ottawa, ON, Canada K1S 5B6. Correspondence to A. C. O'Toole: tel: +1 613 5204377; fax: +1 613 5203539; e-mail: aotoole@connect.carleton.ca.

Introduction

Great barracuda (*Sphyraena barracuda*) have a circumtropical distribution within the western Atlantic Ocean, Caribbean Sea, and Indo-Pacific, and typically inhabit reefs, seagrass beds, and offshore pelagic waters (de Sylva, 1963). It is a piscivorous species (exhibiting lie-in-wait predatory behaviour) and may hold a similar predatory position as elasmobranchs and carangids in nearshore reef environments (de Sylva, 1963). However, to date, there is a relative dearth of information about its biology and life history. Because they are relatively abundant, occupy habitats that are accessible to fishers (Serafy *et al.*, 2007), and readily strike a variety of different lures, great barracuda can be targeted by anglers and by subsistence fishers using angling gear (Springer and McErlean, 1961; de Sylva, 1963; Villareal *et al.*, 2007).

According to the creel survey data collected in southeastern Florida (Harper *et al.*, 2000), some 80% of landed barracuda are released by skilled recreational anglers (60% for all other types of recreational parties combined). Recreational fishing is undertaken by anglers of all skill levels for a range of species throughout the Caribbean and western Atlantic (Mike and Cowx, 1996). It is likely that great barracuda are often encountered as bycatch when anglers are in pursuit of other sportfish such as dolphin (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), and billfish (Istiophoridae), and many of the barracuda incidentally captured are released (Mike and Cowx, 1996; Harper *et al.*, 2000). Ciguatera, a biotoxin-related illness that can lead to neurological and gastrointestinal problems in humans, is often associated with larger barracuda (Lehan and Lewis, 2000) and may further promote discard (release) of barracuda in the recreational sector, although subsistence fisheries largely ignore such risk. In general, there is a paucity of information on the basic biology of barracuda and this is the first study that we are aware of to examine the effects of catch-and-release on this species.

There is a growing body of literature documenting the sublethal impacts of catch-and-release fishing in terms of stress physiology and hooking injury (Cooke *et al.*, 2002a; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005), as well as more than several hundred studies that have documented the short-term mortality associated with catch and release for a range of sportfish (Muoneke and Childress, 1994; Arlinghaus *et al.*, 2007a). In general, there is relatively little knowledge of the consequences of catch-and-release fishing on marine gamefish compared with the broad range of studies completed on freshwater gamefish (Cooke *et al.*, 2002a; Cooke and Suski, 2005), although this is changing with catch-and-release studies in marine environments increasingly being undertaken since the 1990s (Arlinghaus *et al.*, 2007a). Given that recreational fishing contributes to regional economies through revenue generated by tourism (Granek *et al.*, 2008), there is a need to ensure long-term sustainability and high rates of survival in fisheries that release a large proportion of their catch (Cooke *et al.*, 2006). This is especially important in coastal communities or island nations such as The Bahamas where the tourism industry accounts for ~40% of gross domestic product (Government of The Bahamas, 2005). In addition, there is growing recognition of the importance of understanding the consequences of recreational fishing practices on fish welfare (Arlinghaus *et al.*, 2007b), such that efforts can be taken by anglers and managers to ensure that the welfare status of angled fish is maintained (Cooke and Sneddon, 2006; Davie and Kopf, 2006).

Given that the ecological role of apex predators such as barracuda is unknown, but presumably critical for structuring marine ecosystems (Myers and Worm, 2003; Myers *et al.*, 2007; O'Connor and Bruno, 2007; Heithaus *et al.*, 2008), and given that even low levels of post-release mortality can lead to population declines in some marine fish (Schroeder and Love, 2002; Coleman *et al.*, 2004), research on catch-and-release impacts (in terms of lethal and sublethal effects and injury) on barracuda and other large marine fish is needed to ensure the sustainability of the fisheries and to inform managers about potential conservation problems. In addition, because there are broad interspecific differences in terms of morphology, physiology, and behaviour, the response to catch-and-release angling often varies among species (reviewed in Cooke and Suski, 2005).

Many studies have revealed that fish experience some level of physiological disturbance, i.e. changes in glucose, lactate, and ion concentrations, when exposed to catch-and-release angling events (summarized in Cooke and Suski, 2005; Arlinghaus *et al.*, 2007a), including several studies on marine species (e.g. large pelagics, Wells *et al.*, 1986; *Scorpis violaceus*, Lowe and Wells, 1996; *Albula vulpes*, Suski *et al.*, 2007; Cooke *et al.*, 2008). The duration of the angling event, i.e. exercise, may contribute to a range of sublethal effects (behavioural alterations, fitness impacts, physiological disturbance) and post-release mortality (Cooke *et al.*, 2002b; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005). In addition to the potential physiological consequences, investigators have typically quantified hooking injury attributable to catch-and-release fishing in terms of hooking location, extent of tissue damage, and hooking depth measurements (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005). Lure type may influence hooking depth and the severity of injury (Diggles and Ernst, 1997; Bartholomew and Bohnsack, 2005; Arlinghaus *et al.*, 2008b), and deeply hooked fish may experience more bleeding than fish hooked in non-critical areas (Diggles and Ernst, 1997; Cooke *et al.*, 2001; Bartholomew and Bohnsack, 2005; Alós *et al.*, 2008; Arlinghaus *et al.*, 2008b).

We therefore investigated the sublethal physiological consequences, injury, and immediate mortality of great barracuda captured and released in The Bahamas. The first objective of the study was to investigate the extent of physiological disturbance of captured great barracuda relative to angling. We predicted that there would be increased levels of physiological disturbance in fish that were played and handled for longer periods. Our second objective was to determine the types of injury and the extent of immediate mortality arising from catch-and-release angling using a range of common lure types and hook configurations. For this, we predicted that different types of artificial lure (particularly those with multiple treble hooks) would affect the extent of injury, bleeding, hooking depth, and ease of hook removal. We also anticipated that hooking location would affect the ease of hook removal and the amount of bleeding, both of which would influence mortality. Overall, the results contribute to the growing body of knowledge on species-specific responses of fish to catch-and-release angling (Cooke and Suski, 2005), allowing information to be disseminated to anglers (Pelletier *et al.*, 2007).

Methods

Study site and capture method

The study was conducted off the coast of Cape Eleuthera, The Bahamas (24°54′N 76°20′W). Barracuda were captured between December 2007 and January 2009 ($n = 63$) and ranged in total length from 50 to 120 cm. Individual barracuda were captured via typical angling techniques employed by anglers in the Caribbean and western Atlantic Ocean, such as trolling at speeds of 6–9 knots with heavy-action recreational angling gear, e.g. 14 kg (30 lb) test fishing line (Dunaway, 1998).

Three types of artificial lure were used: a hard lure (crankbait or hard topwater lures with two treble hooks, size range 130–170 mm, i.e. Rapala X-Rap Saltwater Lure), a soft lure (soft rubber barracuda tube lure with two treble hooks, size range 350–360 mm, i.e. Hook Up Barracuda Tube Lure), or a single hook lure (a plastic skirted lure such as a tuna candy and mahi popper or a hard lure such as a cedar plug, size range 110–180 mm, i.e. Offshore Angler Blue Water Trolling Bait). All are shown in Figure 1. We chose initially to separate lures adorned with treble hooks into two categories, hard and soft, because we wanted to distinguish potential differences between lures used to target barracuda specifically, i.e. the soft barracuda tube lure, and lures used to target other species, which may consequently result in bycatch of barracuda. All hooks used in the study were barbed as they would be when used by a typical angler in this

Figure 1. Examples of the three types of artificial lure used to capture great barracuda: (a) hard lure with two treble hooks, (b) soft lure with two treble hooks, and (c) single hook lures.

and other related fisheries that may encounter barracuda (ACO'T, pers. obs.). Once hooked, each fish was fought until it could be landed safely in a mesh cradle (rubber-coated knotless nylon, to minimize dermal abrasion and fin fraying; Barthel *et al.*, 2003). Our choices in angling gear and methods were intended to target barracuda for the purposes of the study, but the gear that we used (aside from the barracuda tube lures) are also used commonly to target other gamefish.

The length of time elapsed from the initial strike to landing the fish was recorded as fight time, where the fish was played until exhausted enough to be handled safely and efficiently, i.e. mimicking typical angling methods. During the fight we also recorded instances in which a predator attacked a known barracuda (confirmed either visually before the attack or by the body parts, generally the head, being left on the lure upon landing). Blood sampling time was defined as the time from landing of the fish in the cradle until the blood sample was taken. To focus on the effects of angling duration, we bled each fish before hook removal. As such, its physiological condition at the time of sampling excluded any additional consequences associated with hook removal or air exposure.

Physiological assessment

Upon landing the fish in the mesh cradle, fish were held in a supine position for blood sampling. A 3-ml vacutainer (lithium heparin coated; B-D Inc., NJ, USA) and a 3.8-cm (1.5′) 21-gauge needle were used to collect 2 ml of blood from the caudal vasculature. Once the blood sample was obtained, it was immediately placed in a water–ice slurry. Blood was collected over the side of the boat before bringing the fish into the vessel, then the fish was transferred to a 200-l cooler filled with fresh seawater following phlebotomy, to enable hook removal and assessment. All handling and sampling was carried out with the fish held in water to minimize the amount of air exposure. We did not test for control physiological values, mainly because the purpose of our study was to examine the relationship between stress physiology and the factors directly related to angling, but also because of the difficulty associated with obtaining an accurate measure of undisturbed baseline data in wild fish. Even attempts to hold barracuda in the laboratory have failed owing to the propensity of fish to escape, to attack conspecifics, or not to survive the extended transportation to the laboratory.

Blood glucose, lactate, and ion concentrations are physiological stress indicators commonly documented in catch-and-release studies, because they are relatively simple to obtain and measure in the field, and changes in the concentrations have been associated with exhaustive exercise (Lowe and Wells, 1996; Suski *et al.*, 2007; Cooke *et al.*, 2008). Lactate and glucose concentrations were obtained from whole blood using hand-held lactate (Lactate Pro LT-1710 portable lactate analyser; Arkray Inc., Kyoto, Japan) and glucose (ACCU-CHEK glucose meter; Roche Diagnostics, Basel, Switzerland) meters. Such devices have been calibrated previously for use on fish (Morgan and Iwama, 1997; Wells and Pankhurst, 1999; Venn Beecham *et al.*, 2006; Cooke *et al.*, 2008). Blood was then centrifuged at 10 000 *g* for 6 min, and the plasma was frozen (−20°C) and shipped back to Carleton University, where it was held in a −80°C ultracold freezer until analysis. Ion assays (sodium, potassium, chloride) were conducted on blood plasma using a Roche-Hitachi 917 analyser (Basel, Switzerland). To ensure that the integrity of the analysis was maintained, laboratory personnel followed the Veterinary Laboratory Association Quality Assurance Program, New York State Department of Health, College of American Pathologists, and the Canadian Food Inspection Agency External Proficiency Panel guidelines.

Injury assessment

Once the barracuda had been landed and placed in a cooler of water, hooking injury was assessed. Hooking depth (measured from the tip of the snout to the point of hook entry) was measured for each fish and corrected for the total length for comparison between fish of different sizes (documented as the proportion of hooking depth to total length of the fish, as outlined by Cooke *et al.*, 2001; herein termed "length-corrected hooking depth"). Hooking location was categorized as critical (gills, gullet, eye) or as non-critical (jaw, hinge, roof of mouth, foul-hooked in body) using similar criteria to those developed by Meka (2004) and Arlinghaus *et al.* (2008b). Angling-related injury was then quantified as minor (minimal or no tissue damage, and fewer than two cumulative injuries in non-critical areas) or severe (hooked in a critical location such as the gills, gullet, or eye, and three or more cumulative injuries including tissue damage, foul-hooking, and line-wrap). Bleeding (present or absent) and ease of hook removal (easy <30 s to remove; difficult >30 s to remove) were also recorded. Full injury assessments and hook removals were completed within 2 min of the blood sample being obtained with the fish submerged. Fish were also assessed for evidence of immediate mortality. Immediate mortality was based on whether a fish had lost gill colour and fin perfusions and/or was unable to maintain equilibrium after 5 min of resuscitation. Once fish were able to maintain equilibrium independently (many fish required resuscitation), they were released near the point of capture.

Statistical analyses

Linear regressions were used to test the relationships of both fight time and blood sampling time with physiological response variables (i.e. glucose, lactate, sodium, potassium, chloride; Zar, 1999). Where the assumption of residual normality was not met, any outliers were removed (assessed as being outside the 95% confidence interval) and glucose data were $\log_{10}$-transformed. We were unsuccessful with obtaining blood from all fish, resulting in differing sample sizes between some analyses. Contingency table analysis was used to determine the relationships between categorical variables such as lure type or hook location and injury, ease of hook removal, and bleeding (Zar, 1999). Upon visualizing the data, there was some evidence that hook type (i.e. two treble hooks vs. one single hook) could represent a more informative analysis for ease of hook removal, and an additional contingency table analysis was performed to test this. The effect of lure type on hooking depth was analysed using one-way analysis of variance (ANOVA). Hooking depth was corrected for the total length of the fish and $\log_{10}$-transformed to meet the assumptions of normality and homogeneity of variance. All statistical analyses were conducted using the statistical software program JMP v. 7.0 (SAS Institute, Raleigh, NC, USA), and the results were assessed for significance at $\alpha = 0.05$.

Results

Physiological parameters

In all, 63 great barracuda were angled near Cape Eleuthera, The Bahamas, between December 2007 and January 2009. During the study, the water temperature range was 21–29°C and mean water temperature 24.2 ± 0.2°C. Fish ranged in size from 50 to 120 cm total length, with an average length (±s.e.) of 85.5 ± 1.8 cm. The mean (±s.e.) fight time was 175 ± 9 s and the mean blood sampling time (±s.e.) was 190 ± 16 s. A positive relationship with blood glucose concentrations was seen for both fight time ($r^2 = 0.14$; $F = 9.80$; d.f. = 1, 56; $p = 0.003$; Figure 2a) and blood sampling time ($r^2 = 0.27$; $F = 17.12$; d.f. = 1, 46; $p < 0.001$; Figure 2b). A positive relationship also existed between plasma sodium and fight time ($r^2 = 0.07$; $F = 4.25$; d.f. = 1, 49; $p = 0.04$; Figure 3a) and blood sampling time ($r^2 = 0.16$; $F = 7.99$; d.f. = 1, 43; $p = 0.007$; Figure 3b). There was no effect of fight time on lactate concentration ($r^2 = 0.03$; $F = 2.06$; d.f. = 1, 57; $p = 0.16$; Figure 2c), but there was a positive relationship between blood sampling time and lactate concentration ($r^2 = 0.12$; $F = 6.87$; d.f. = 1, 48; $p = 0.01$; Figure 2d). We found no trends in plasma ion concentrations for either potassium or chloride according to fight time (potassium $r^2 = 0.02$; $p = 0.27$; chloride $r^2 = 0.03$; $p = 0.23$; Figure 3c and e) or blood sampling time (potassium $r^2 = 0.03$; $p = 0.23$; chloride $r^2 = 0.04$; $p = 0.17$; Figure 3d and f). The mean (± s.e.) physiological values for barracuda (the first ever reported) were 3.8 ± 0.2 mmol l^{-1} blood glucose, 3.9 ± 0.2 mmol l^{-1} blood lactate, 199 ± 1.1 mmol l^{-1} plasma sodium, 5.7 ± 0.2 mmol l^{-1} plasma potassium, and 177 ± 1.4 mmol l^{-1} plasma chloride.

Injury

Contingency table analysis results did not reveal an association among the three lure types and the extent of injury ($\chi^2 = 5.77$; d.f. = 2; $p = 0.06$; Figure 4a), presence of bleeding ($\chi^2 = 2.60$; d.f. = 2; $p = 0.27$; Figure 4b), or ease of hook removal ($\chi^2 = 2.79$; d.f. = 2; $p = 0.25$; Figure 4c). One-way ANOVA also failed to reveal differences among the three lure types and the mean length-corrected hooking depth ($F = 1.21$; d.f. = 2; $p = 0.31$; Figure 4d). Although there was no significant difference in the ease of hook removal among the three lure types, >28% of lures adorned with treble hooks required >30 s to remove them compared with just 9% of the single *j*-style hook lures.

Only two fish (3%) were hooked in critical locations (i.e. eye, gills). Non-critical hooking locations were mainly in the jaw (68%) and hinge (17%), or a few in the roof of the mouth and the exterior of the body (6 and 9%, respectively). Of the fish hooked in non-critical locations, 88% had hooks that were easily removed and experienced minimal or no bleeding. However, both individuals that were hooked in critical locations bled from the hook wound and the hooks were difficult to remove, because these areas were in proximity to delicate tissue, i.e. gills, stomach, eye. Upon hook removal, some fish did appear to have significant tissue damage, i.e. small flaps of skin and tissue hanging from the jaw, and it is unknown how barracuda heal post-release.

Mortality

Of the 63 barracuda landed during the study, none experienced immediate mortality, but five (8%) lost equilibrium post-capture. These fish appeared to expel gas from their vent when ventral pressure was applied. Within 5–10 min, the barracuda were able independently to maintain buoyancy and regain equilibrium. Two barracuda were killed during the angling event when they were attacked by unknown predators (either conspecifics or sharks). Given these attacks, we made the observation that ~3% of fish hooked securely enough to be played for long periods were attacked and killed by predators.

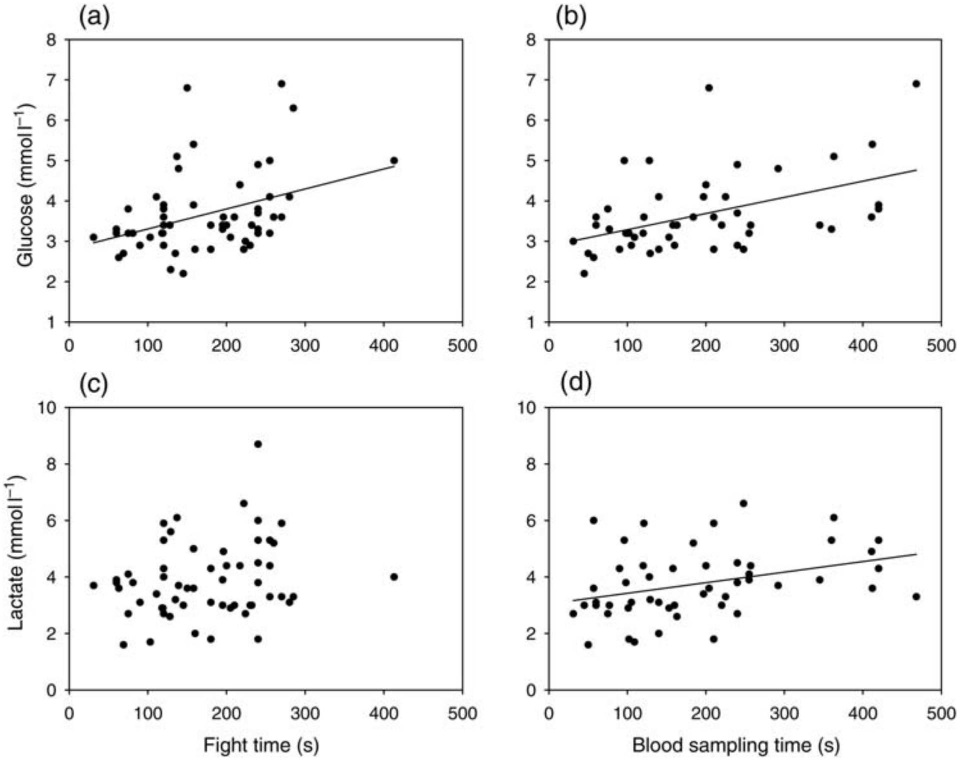

Figure 2. Relationships between blood glucose concentration (mmol l^{-1}) and (a) fight time and (b) blood sampling time, and blood lactate (mmol l^{-1}) concentration and (c) fight time and (d) blood sampling time for great barracuda caught by hook-and-line angling.

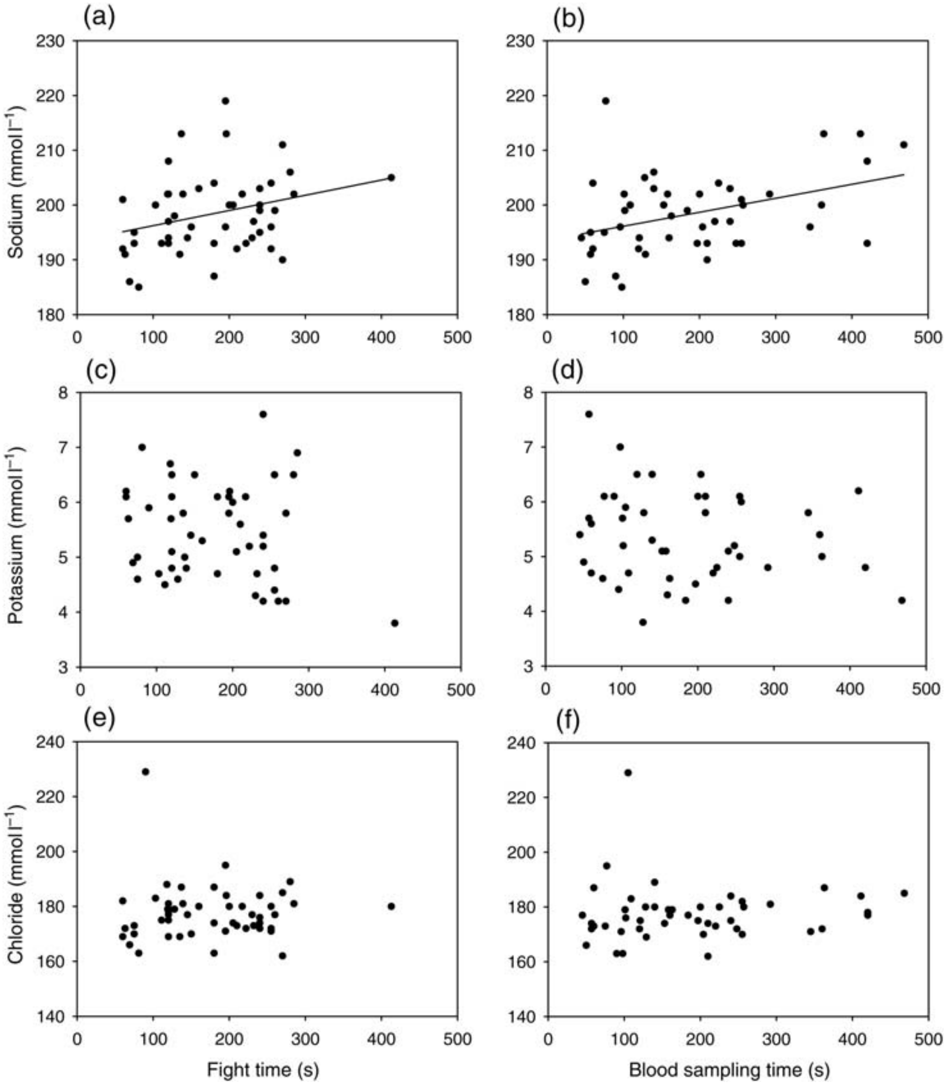

Figure 3. Ionic parameters measured in blood plasma of great barracuda caught by hook-and-line angling. Relationships between sodium concentration (mmol l^{-1}) and (a) fight time and (b) blood sampling time, and potassium concentration (mmol l^{-1}) and (c) fight time and (d) blood sampling time, and chloride concentration (mmol l^{-1}) and (e) fight time and (f) blood sampling time.

Discussion

With the dearth of information on the basic biology of great barracuda as well as the general lack of catch-and-release studies published on marine species, there is value in understanding the physiological response of barracuda to recreational angling. Results from this study may contribute to educational material that would enhance awareness among anglers of the need to reduce potential sublethal stress and mortality for angled barracuda. Compared with other fish species with which we work regularly, obtaining a blood sample from great barracuda proved to be relatively difficult (blood was relatively slow to draw; ACO'T and SJC, unpublished data), presumably because of the vascular morphology of the fish. This factor often increased blood sampling time (at times doubling the time needed to interact with the fish) and despite our best efforts to minimize air exposure and handling, concentrations of glucose, lactate, and sodium likely increased from the moment the fish was landed until the blood sample was obtained. Burst-swimming during an angling event can lead to depleted tissue energy stores and an increase in plasma glucose (Kieffer, 2000; Barton *et al.*, 2002; Frisch and Anderson, 2005). Cumulative stressors may also result in elevated levels of physiological disturbance (Barton *et al.*, 1986; Kieffer, 2000; Cooke and Suski, 2005), e.g. longer angling duration followed by prolonged handling times.

Although no changes in blood lactate concentrations with fight time were observed, it is common for angled fish to experience an accumulation of lactic acid as a result of anaerobic metabolism associated with exhaustive exercise (Kieffer, 2000; Barton *et al.*, 2002; Meka and McCormick, 2005; Cooke *et al.*, 2008). However, with the positive relationship between blood lactate levels and blood sampling time, perhaps lactate values immediately post-exercise had not yet peaked in the blood and were continuing to rise as the fish was handled and even after the blood sample was obtained. We were unable to obtain control physiological values for barracuda because we had limited holding facilities and transporting such large fish to the laboratory would have been very difficult (a common limitation in catch-and-release studies; Cooke and Schramm, 2007). Unfortunately, the lack of

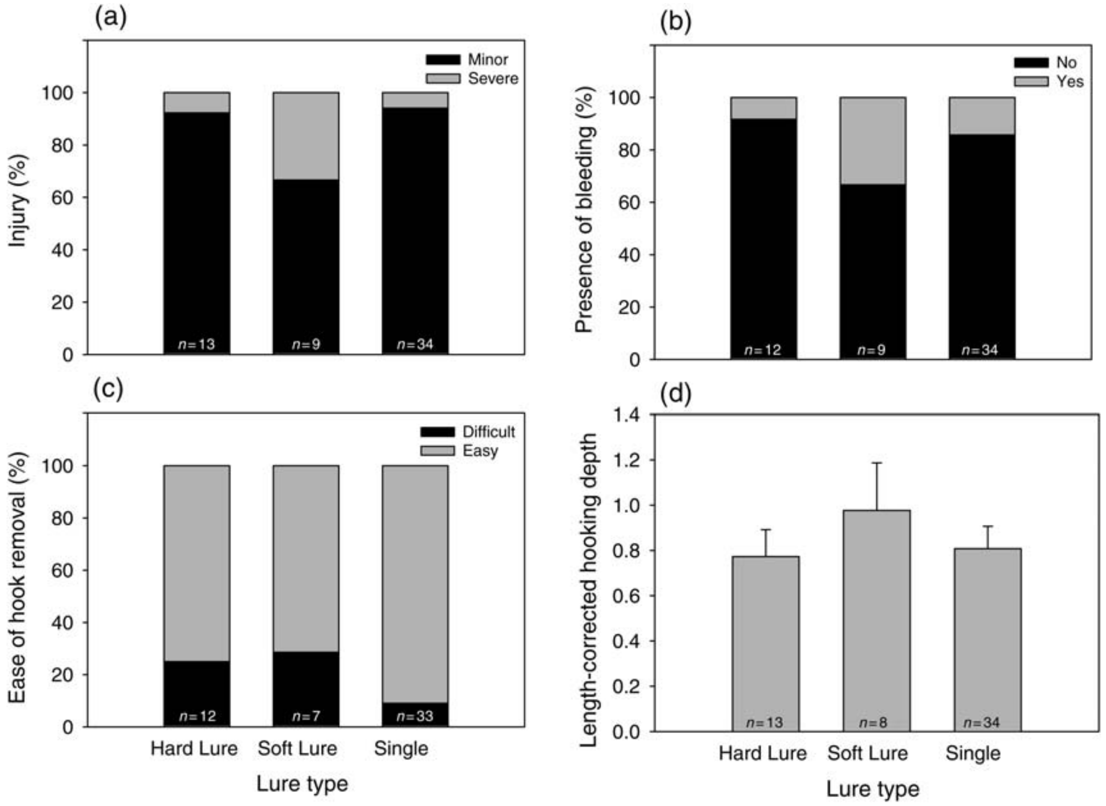

Figure 4. The effect of lure type (hard lure, soft lure, single hook lure) on (a) injury, (b) presence of bleeding, (c) ease of hook removal, and (d) length-corrected hooking depth. All statistical tests were non-significant and sample sizes are provided for each lure category.

baseline physiological data specific to this species made it difficult to determine the extent of physiological disturbance that arises from the angling event itself. In general, the blood lactate values recorded were relatively low (e.g. 3.9 ± 0.2 mmol l^{-1}) compared with those obtained for other fish angled for similar durations, e.g. 5–7 mmol l^{-1} for northern pike (*Esox lucius*; Schwalme and MacKay, 1985), 5–8 mmol l^{-1} for rainbow trout (*Oncorhynchus mykiss*; Meka and McCormick, 2005), and 4–6 mmol l^{-1} for bonefish (*A. Vulpes*; Cooke *et al.*, 2008). In addition, a certain amount of variation around the regression lines was noted for the glucose and lactate relationship with fight time and blood sampling time (Figure 2). Variation in this case may be attributed to individual differences, and this variation could possibly be reduced with a larger sample.

Ionic changes are also indicators of physiological stress caused by exhaustive exercise (Wells *et al.*, 1986; Wood, 1991), although only a few studies have tested the relationship between angling duration and ion imbalance in marine teleosts (e.g. Wells *et al.*, 1986; Thompson *et al.*, 2002; Cooke *et al.*, 2008; Fabrizio *et al.*, 2008). Wells *et al.* (1986) showed that K^+, Na^+, and Cl^- all increased in capture-stressed large pelagic species, whereas bonefish did not experience any relationship between fight time and plasma ion levels (Suski *et al.*, 2007; Cooke *et al.*, 2008). The release of stress hormones in marine fish is associated with osmoregulatory difficulty, which may lead to hydromineral imbalance (Eddy, 1981; Barton *et al.*, 2002). Stressors such as long fight times trigger the release of corticosteroids and catecholamines, which may increase gill permeability and alter ionic balance (Moyle and Cech, 2000). Therefore, in marine teleosts, a stress response could include a loss of water and a gain of ions across the gills (Wells *et al.*, 1986; Moyle and Cech, 2000). Although plasma sodium increased with fight time and blood sampling time, similar trends in plasma chloride concentrations were not apparent in the present study, despite expectations that increased NaCl uptake (from seawater) and a loss of water across the gills would result as a stress response in angled barracuda.

Hook location influences the ease of hook removal (lengthening air exposure, contributing to physiological stress, and increasing the risk of post-release mortality), and fish hooked deeply tend to experience more bleeding than fish hooked in non-critical areas, because a fish that is excessively bleeding upon release may bleed to death or be more susceptible to predation (Diggles and Ernst, 1997; Cooke *et al.*, 2001; Prince *et al.*, 2002; Bartholomew and Bohnsack, 2005; Arlinghaus *et al.*, 2008b). In this study, lure type did not affect relative hooking depth, severity of injury, bleeding, or ease of hook removal for captured great barracuda. We had predicted that lure type would influence the severity of injury, particularly for lures with multiple treble hooks, but the results showed uniform levels of injury among lure types, perhaps because of the limitations of small resultant sample sizes in some treatment groups and the lack of fish that were severely injured or hooked in critical areas. Barracuda are ambush predators that strike their prey at high speeds, exhibiting ram-biting behaviour where prey is initially impacted at the corner of the mouth (Grubich *et al.*, 2008). Striking a lure would happen in a similar fashion, so that the hook would likely penetrate the mouth or jaw instead of deeply hooking the barracuda in the gullet or gills. The amount of bleeding at the site of the hook wounds was minimal, because great barracuda may have less perfused tissues in their jaw area, potentially as an adaptation to prevent excessive bleeding when preying on fish with spines and hard appendages. Muskellunge (*Esox masquinongy*) and northern pike (*E. lucius*), two freshwater species with similar morphology and feeding behaviour, also exhibit little bleeding when hooked in the jaw (Ostrand *et al.*, 2006; Arlinghaus *et al.*, 2008b).

There was no immediate mortality in this study, but because post-release predation of barracuda is possible, all the fish captured were allowed to revive, including to regain the ability to maintain equilibrium independently, before being released. Gamefish released in marine waters can experience post-release predation, although this phenomenon has not received much attention (Jolley and Irby, 1979; Edwards, 1998; Cooke and Philipp, 2004; Danylchuk *et al.*, 2007; Henderson, 2009), this study was unable to quantify post-release mortality. On some occasions, other large predatory fish, i.e. carcharhinids, carangids, other barracuda, followed the hooked barracuda right up to the boat, likely attracted to the noise and movement produced by the angled fish or by olfaction (Moss, 1977; Bleckmann and Hofmann, 1999). Although not quantified in this study, many barracuda were lost when they cut or broke the line despite the use of a wire or heavy monofilament leader. The fate of barracuda that break-off and retain the lures is unknown. In fact, just two studies currently exist on the fate of gamefish released with lures in their mouth, for northern pike by Arlinghaus *et al.* (2008a), and for smallmouth bass (*Micropterus dolomieu*) by Henry *et al.* (2009). Lure retention may result in behavioural and physiological alterations and would be an issue worth examining for great barracuda.

Although angled barracuda appear to be fairly robust and immediate mortality was negligible, we are uncertain as to the extent of delayed mortality, particularly that associated with post-release predation, a topic requiring work. No differences were observed in the extent of injury caused by three common lure types, so choosing lures with single hooks and having pliers or haemostats accessible will expedite quick hook removal, reduce handling, and decrease air exposure. When targeting great barracuda, it would appear to be expedient to run lines short when trolling to reduce fight time, to land the fish in a knotless mesh net or cradle for ease of handling and then remove the hook over the side of the vessel without removing the fish from the water to minimize air exposure. Predictions of specific effects of angling on great barracuda will contribute to future management decision-making (Cooke and Suski, 2005; Coggins *et al.*, 2007), and given that barracuda are often taken as bycatch when anglers are targeting other gamefish, there may well be benefit in educating anglers and guides on the importance of predators such as barracuda to promote better handling and release practices for what we believe many anglers regard as a nuisance fish.

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