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EXTENDED ABSTRACT

The Physiological Effects of Angling on Post-Release Survivorship in Tunas, Sharks, and Marlin[1]

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Large numbers of tunas, sharks, and marlin are released annually by recreational and commercial rod-and-reel fishermen off the east coast of the United States. This is largely due to the federal imposition of quotas, minimum sizes, and bag limits on offshore anglers, coupled with a growing conservation ethic. Catch data collected in Massachusetts from 1991 to 1998 indicate that, on average, 96% of the blue sharks *Prionace glauca*, 75% of the school bluefin tuna *Thunnus thynnus*, 30% of the yellowfin tuna *Thunnus albacares*, and 99% of the white marlin *Tetrapturus albidus* were released annually by big game tournament participants. However, the extent to which angling affects post-release survivorship is unknown in these species. Increased angler-induced mortality will have important implications in release and quota management strategies.

Tunas, sharks, and billfish possess large amounts of anaerobic white muscle that reflects an ability of high work output in short bursts. Angling practices result in increased anaerobic activity, muscular fatigue, and time out of water. The physiological consequences of angling stress are poorly understood in large pelagic fishes. Available evidence supports the notion that high anaerobic muscular activity in fish causes extreme homeostatic disruptions that may impede normal physiological and behavioral function and, ultimately, reduce survivorship (Wood et al. 1983; Wood 1991; Milligan 1996). Since blood reflects changes in muscle biochemistry, these perturbations can be measured and quantified (Wells et al. 1986).

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During the period 1993–1998, a two-tiered approach was used to quantify and evaluate the physiological effects of angling on post-release survivorship in large pelagic game fish. First, to quantify the physiological consequences of high anaerobic muscular exercise, blood was sampled from 312 fish comprising 12 species of tunas (230), sharks (77), and marlin (5), after exposure to rod-and-reel angling. Samples were also collected from electroshocked, free-swimming bluefin tuna (13), free-swimming blue sharks (2), and sharks caught on longline (61). Physical and environmental conditions related to each angling event were recorded and correlated to blood chemistry parameters. Secondly, to assess post-release behavior and survivorship relative to blood chemistry perturbations, blood-sampled tunas, sharks, and marlin were tagged with conventional tags and/or ultrasonic telemetry tags.

A preliminary analysis of blood chemistry data from 122 bluefin tuna, 64 yellowfin tuna, and 72 blue sharks was conducted relative to fight time; data from five white marlin were included for comparative purposes. Blood gases, pH, lactate, cortisol, and serum electrolyte, metabolite, and protein profiles show that these four species exhibited significant homeostatic perturbations as a consequence of extreme exhaustive exercise. Interspecific differences were found relative to the magnitude and nature of these disturbances; disruption was greatest in the tunas. The primary response to stress included a significant elevation of blood cortisol in bluefin tuna, yellowfin tuna, and white marlin. In the tunas, a significant increase occurred 10 minutes into the angling event. Although limited by sample size, cortisol levels measured in the white marlin were among the highest reported for any fish. Secondary effects included a significant drop in blood pH, elevations in blood lactate, and changes in serum electrolyte levels. These changes occurred after 5 minutes of exercise in the bluefin and yellowfin tunas, but took 20 minutes to develop in the blue shark (Table 1; Figure 1). Blood gas data indicate that this acidemia had both a metabolic and respiratory origin in the two tunas, but only metabolic in the blue shark.

Six blood-sampled fish that were tagged and released were subsequently recaptured: two bluefin tuna, one yellowfin tuna, and three blue sharks. Blood chemistry data from these fish indicated that the level of stress was commensurate with fight time. A total of 15 acoustic tracks were conducted on 7 bluefin tuna, 4 blue sharks, 2 yellowfin tuna, and 2 white marlin. These fish were exposed to prolonged angling bouts (mean = 46 minutes) and blood chemistry data were indicative of greater than average levels of stress. With the exception of one bluefin tuna, all tracked fish survived for the duration of the tracks, which ranged from 2 to 24 hours. All surviving fish exhibited distinct post-release recovery periods of two hours or less, characterized by limited vertical activity. It is

Table 1: Species-specific sample sizes for blood pH data in Figure 1.

Fight time Interval (min)	*Bluefin tuna*	*Yellowfin tuna*	*Blue shark*	*White marlin*
0	6	11[a]	1	
5	8	6	2	
10	18	24	5	
15	14	6	2	
20	11	4	2	
25	3	2	2	
30	4	1	4	
35	3	1	2	1
40	1			
45		1		1
50		1		1
55				1
60	1			
Total	69	46	20	4

[a] derived from Brill et al. 1992

hypothesized that physiological disturbances are corrected during this period. Moreover, fish may be vulnerable to predation at this time.

A single bluefin tuna angled for 42 minutes died immediately after release. This fish had a depressed blood pH and high blood lactate levels indicative of a severe acidemia. However, two surviving bluefin tuna exposed to longer angling bouts exhibited more extreme acid–base disruptions. The notable dif-

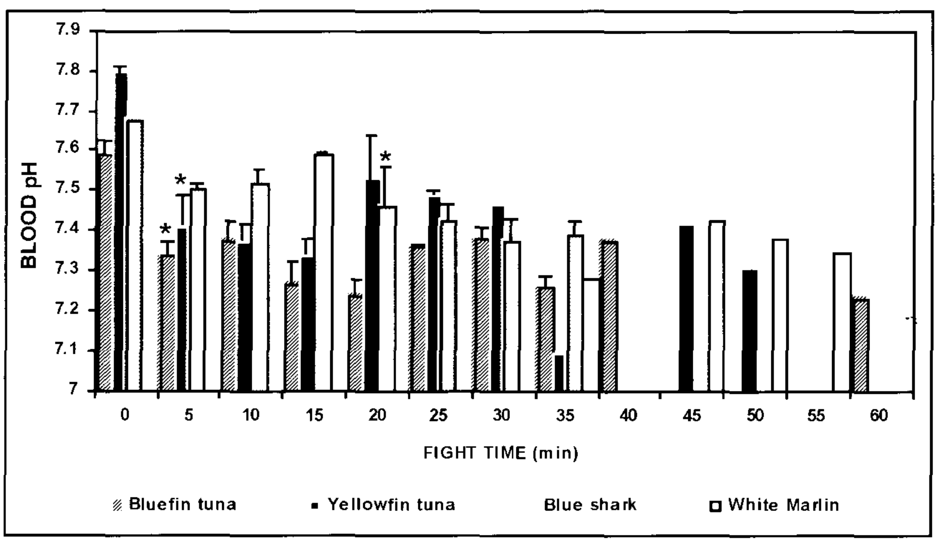

Figure 1. Changes in blood pH relative to fight time for bluefin tuna, yellowfin tuna, blue sharks, and white marlin; mean + SEM. * indicates significant change (analysis of variance (ANOVA), $p < 0.05$).

ference between these fish was that the single mortality was not resuscitated at the side of the vessel before release. It is hypothesized that the five to seven minutes of resuscitation given to the latter two fish allowed for carbon dioxide offloading and oxygen delivery. In the single mortality, it is possible that muscular fatigue associated with the angling bout precluded obligatory ram ventilation after release, leading to respiratory failure.

The results of this study support the hypothesis that pelagic game fish are capable of recovery when handled properly and not subjected to extensive physical trauma. In addition, when the duration of the angling bouts was minimized, the magnitude of the acidemia was reduced, thereby potentially reducing the vulnerability of fish to predation during the recovery period. Moreover, resuscitation of tunas and marlin after angling bouts in excess of 15 minutes may enhance survivorship.

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