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Keyword:	Southern Bluefin Tuna, recreational fishing, physiological stress, post-release survival, responsible fishing

Capture-induced physiological stress and post-release mortality for Southern bluefin tuna (*Thunnus maccoyii*) from a recreational fishery

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Abstract: Southern bluefin tuna (SBT) are a popular component of the recreational large pelagic game fishery in Australia. The fishery is managed using individual fisher catch limits. Fifty-nine pop-up archival transmitting (PAT) tags were attached to individual SBT to estimate post-release survival (PRS) rates. Fish caught on lures configured with J-hooks (n = 44) and those caught on circle hooks (n = 8) had similar PRS rates and were combined to increase sample size, revealing a PRS estimate of 83.0% (95% CI: 75.9 – 90.7%, n = 54). The PRS estimate of fish caught on lures with treble hooks was much lower, 60% (95% CI: 20 – 100%, n = 5). By sampling blood from 233 fish, including 56 of the PAT tagged individuals, we show that angling duration is related to an elevation of lactate, cortisol and osmolarity in blood plasma, indicative of increased physiological stress. Physical damage related to hooking location, angling duration, biochemical indicators of physiological stress and handling duration were not identified as significant factors leading to post-release mortality. The results quantify a previously un-accounted source of mortality for SBT.

Keywords: Southern Bluefin Tuna, *Thunnus maccoyi*, recreational fishing, physiological stress, post-release survival, responsible fishing, animal welfare

Introduction

Southern bluefin tuna (*Thunnus maccoyii*) are a prized target of recreational fishers in Australia. The species is targeted when the fish seasonally migrate close to the south and southeast coastline, within range of recreational fishing boats (Green et al. 2012; Tracey et al. 2013). Historical overfishing by the commercial fishery, comprising fleets from several countries, has reduced the population of southern bluefin tuna (SBT) to 8 – 12% of the pre-exploitation spawning biomass (CCSBT 2014). While it is unlikely that the Australian recreational harvest of SBT is significant relative to the global TAC, there is an obligation for member countries to report all sources of mortality from within their EEZ to the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) to provide a complete and transparent estimate of harvest (CCSBT 2014). As such, quantifying fishing mortality arising from the recreational sector is important (CCSBT 2014; Marcek and Graves 2014).

Recreational fishers in Australia are allowed to retain SBT, however this is regulated by individual possession limits. Some fishers also choose to not retain fish, referred to as catch and release fishing. Catch limits are traditional tools used globally as a principal means to manage recreational fisheries (Bartholomew and Bohnsack 2005; Tetzlaff et al. 2013). A fundamental assumption under-pinning the effectiveness of catch limits, as well as voluntary catch and release, is that most fish survive (Cooke and Suski 2005; Arlinghaus et al. 2007; Cooke and Schramm 2007; Tetzlaff et al. 2013) and that fish suffer minimal sub-lethal effects once released (Arlinghaus et al. 2009). Recent reports indicate that approximately 25% of SBT caught by recreational fishers in Australia are released (Green et al. 2012; Tracey et al. 2013). Hence, a low post-release survival rate may lead to a significant source of unaccounted mortality relative to the recreational harvest of SBT.

For many species little is known about the fate of fish after release. Over the last decade, however, there has been a growing body of literature investigating factors that may cause excessive stress or damage to a fish as well as assessing post-release survival rates. Significant variability has been reported in post-release survival rates between species (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005; Arlinghaus et al. 2007; Cooke and Schramm 2007). This highlights the importance of investigating post-release survival on a species-by-species basis.

Assessing post-release survival of highly migratory fish is logistically challenging (Moyes et al. 2006; Donaldson et al. 2008). Conventional tagging studies typically yield low return rates (Kohler et al. 1998). Active tracking of animals for a sufficient period post-release using acoustic technology is difficult due to the swimming speed and dispersal range of large pelagic fish (Skomal 2007). While containment experiments are generally not feasible due to the scale of equipment required to hold the fish (Skomal 2007).

The most common approach to assess the fate and behaviour of large pelagic fish after release is the application of pop-up archival transmitter (PAT) tags. This method has been applied to assess survival of large sharks (Skomal and Chase 2002), billfish (Graves et al. 2002; Domeier et al. 2003; Kerstetter et al. 2003; Kerstetter and Graves 2006) and tunas (Stokesbury et al. 2011; Marcek and Graves 2014).

The capture of a fish will always have some impact; at the very least the fish is hooked and fought for a period of time, resulting in some physical exertion (Cooke and Suski 2005; Arlinghaus et al. 2007). Factors such as angling duration, water temperature and air exposure have all been shown to induce a physiological stress response (Cooke and Suski 2005). The resulting adaptive physiological responses to stressors that occur during capture can be measured via biochemical reactions (Moyes et al. 2006). Furthermore, stressors can be tested against the fate of the fish to assess whether fishers can alter their practices to maximise post-release survival and minimise fish welfare impacts (Moyes et al. 2006).

Species-specific information on the effects of capture and handling by recreational fishers can be utilised in the development of scientifically defensible best practices, minimising the impacts of recreational fishing activities on released fish and fish stocks as a whole (Cooke et al. 2012). Importantly, this information enhances the sustainable utilisation of fisheries resources by considering additional sources of mortality in stock assessment and providing results that facilitate informed decision making by fishers, increasing resource stewardship.

In this study, the post-release survival rate of SBT caught in the Australian recreational fishery was evaluated. In addition, a range of factors related to the catch, handling and release of SBT were assessed and tested against physiological stress indicators measured by biochemical variables. Finally, capture factors and physiological stress indicators were tested to assess causality of post-release mortality.

Methods

Southern bluefin tuna were caught in waters southeast of Tasmania in 2012-14, and in waters adjacent to southwest Victoria and the South coast of New South Wales (NSW) in 2013 and 2014 (Fig. 1). Sampling occurred between February and July each year. All fish were caught using standard recreational fishing techniques, specifically rod and reel fitted with 15, 24 or 37 kg breaking strength monofilament line. Lures were standard, commercially available products commonly used by the recreational fishery to target SBT, including hard-body lures with either J-hooks (6/0) or treble hooks (4/0) and skirted lures with single J-hooks (9/0). All lure configurations were trolled at 6 – 9 knots. Baited circle hooks (7/0) were used on occasion when fishing adjacent to NSW. These were presented to schools of fish while the boat was drifting.

Hooked fish were retrieved to the boat and carefully lifted on-board and the angling duration (time from lodging hook until retrieved to the boat) recorded. Fish were placed on a padded mat and the eyes covered with a wet towel, following the methods considered 'best practice' for responsible fish handling. Fish were not irrigated during the handling process as this was considered beyond the scope of what is promoted as 'best practice' for recreational fish handling. Immediately after the fish was landed a non-lethal blood sample was taken (0.5 – 3.0 ml) from the lateral artery posterior to the pectoral fin or by cardiac puncture using a lithium heparin Vacutainer® (Becton-Dickinson) with a 38 mm 21-gauge needle. Blood samples were placed on ice until further processing. Fork length (*FL*) was measured to the nearest cm, the condition of the fish was assessed (1 = vigorous, 2 = active, 3 = low active or 4 = dead), the location of the hook and severity of bleeding recorded (1 = none, 2 = minor external, 3 = minor internal or 4 = major bleeding), and the hook removed. At release, fish were held alongside the boat, which was slowly moving forward, until it freely kicked from the grip of the handler. This resuscitation technique is recommended to the recreational fishery as 'best practice' for releasing southern bluefin tuna. The release location as reported by a GPS and the time out of water (handling time) were then recorded.

Pop-up archival transmitter tags

Fifty-nine fish were released with pop-up archival transmitter (PAT) tags (MiniPAT; Wildlife Computers, Redmond, WA, USA) regardless of bleeding or hooking location. To minimise the potential for mortalities related to carrying a satellite tag only fish greater than 90 cm FL were tagged. All 21 fish caught adjacent to NSW were tagged. Only a proportion of fish caught from VIC (n = 14) and TAS (n = 24) were tagged as a greater number were caught from these locations than tags available, with many fish of a similar size. Fish to be tagged were selected at random and approximately proportional to the total number of fish caught within 10 cm length (*FL*) bins, spanning the size distribution of all fish caught. Each tag was rigged with a Domeier nylon umbrella dart tag anchor via stainless steel wire. The anchor was inserted into the musculature at the base of the second dorsal fin and through the pterygiophores. A second Domeier umbrella anchor crimped to a 24 kg monofilament loop, was attached approximately 5-10 cm behind the primary tagging location to minimise lateral tag movement.

Fifty-four tags were programed to detach after 180 days, the remaining five were programed for shorter retention durations (Table S1). Each tag was programmed to release from the anchored tether at the conclusion of the programmed period via a corrodible release pin. Alternatively, if the tag sank to a depth greater than 1800 m or the depth recorded by the tag did not change by greater than ± 2.5 m over a 2-day period the tag was also programmed to detach from the tether. Detached tags floated to the sea surface and transmitted data to the Advanced Research and Global Observation Satellite (ARGOS) system. By examination of dive and temperature profiles in the hours and days after release a determination was made as to the fate of each tagged fish (Fig. 2).

Sea-surface temperature (SST) at the time of capture was identified by the first temperature record on a tag at a depth less than ten meters on the day of tagging. For fish that were not satellite tagged, location specific SST at time and location of capture were derived from Advanced Very High Resolution Radiometer (AVHRR) satellite estimates accessed through the Integrated Marine Observing System (IMOS).

Physiological stress

Whole blood lactate and glucose were measured in the field, the former with a Lactate Pro LT-1710 (Arkray, Kyoto, Japan), the latter with an Accu-Chek Active (Roche, Mannheim, Germany). The remaining blood sample was centrifuged for five minutes at 3300rpm using a portable field centrifuge (LW Scientific Portafuge). The resultant blood plasma was stored in liquid nitrogen (~ -80°C) until subsequent laboratory analysis.

For samples where there was sufficient blood plasma, glucose and lactate were analysed in the laboratory using a GM7 Microstats reader (Analox Instruments, Helena Laboratories, VIC, Australia). Given the laboratory analysis was a more accurate method the values from field meters were converted to laboratory values based on the parameters of significant linear relationships. pH was measured using a Minilab Isfet pH meter, Model IQ125 (Hach Pacific, Victoria, Australia).

Quantitative determination of cortisol was conducted using an ENZO Cortisol Enzyme Linked Immunosorbant Assay (ELISA) kit (United Bioresearch Products Pty Ltd, NSW, Australia). Standards and samples diluted 1:5 to 1:100 were prepared and assayed according to manufacturer instructions. Microtitre plates were read at 405nm using a TECAN

Genios plate reader (TECAN Australia Pty Ltd). Parallelism of diluted plasma with the standard curve was confirmed according to Plikaytis et al. (1994). Slopes for the reference standards and serially diluted serum were 161.76 and 161.76, respectively. Inter-assay coefficient of variation (CV) using high and low standard reference points was <10%. Intra-assay CV using high, moderate and low plasma samples was similarly <10%. Recovery of cortisol from a spiked plasma sample was 101.2%. Spiked and diluted sample recoveries percentage limits of within 90–110% were considered acceptable.

Statistical analysis

Data analysis was conducted using R 3.0.3 (R Core Team 2014). The relationships between predictor variables related to the capture process (severity of bleeding, angling duration, fish length and sea surface temperature at the site of capture) to each of the biochemical variables were investigated using generalised additive models (GAMs) (Zuur et al. 2009). Outliers were removed based on visual interpretation of box plots. The error structure of each GAM was determined by the fit to the data with the aim of satisfying the assumption of normality. Correlations between variables were explored and the existence of collinearity between covariates was identified using the variance inflation factor (VIF). The upper threshold value of the VIF was set at ‘3’ which has been identified as a robust approach (Zuur et al. 2010). If collinearity was identified the variables with the highest VIF values were sequentially removed until all VIF values were less than the threshold (Zuur et al. 2009; Zuur et al. 2010).

The initial, full factorial model was:

$$V_{blood} = a + s_{FL}(FL) + s_{AD}(AD) + s_{SST}(SST) + BL + \in$$

where α is the GAM intercept, FL is fork length, AD is angling duration, SST is sea surface temperature, BL is the ordinal severity of bleeding index, ε is an error term and s are thin-plate spline smoothers. The amount of smoothing (k) applied to the splines was restricted to avoid over-fitting due to sample size, but adequate to describe the non-linearity between the response and explanatory variable.

For each GAM, a stepwise backward selection method was applied beginning with all predictor variables. Non-significant variables with the lowest significance levels were excluded at each step and the model run again until only significant predictors remained. The goodness of fit for each of the reduced models was considered using the unbiased risk estimator (UBRE), the level of deviance explained, and the lowest Aikake's Information Criterion (AIC) as per (Zuur et al. 2009). The GAMs were fitted using the mgcv package in R. The significance level was set to $\alpha = 0.05$ for all tests.

Post-release survival was categorised as a binary fate ('survived' or 'died'). A decision rule was implemented to assign a mortality as either related to the capture event or as a natural mortality. A Kaplan-Meier survival analysis was used to visualise tag retention and mortality events through time. The maximum duration considered was 180 days governed by the detachment date and time programmed on-board the tag. Mortality related to the fishing event was considered to have occurred if the tag indicated the fish had died within 10-days post-release. This assumption was based on the behaviour of the fish prior to the mortality event determined from the recorded dive profile, a natural break in the cumulative number of fish identified as dying after this time and existing literature. Mortalities beyond this point were considered natural mortalities. The 95% confidence interval associated with post-release survival estimates were calculated using the release mortality software (version 1.1.0) (Goodyear 2002). Confidence intervals were based on 10,000 simulations. One premature release that occurred within the 10-day period was included in the model as a 'survivor' based on the interpretation of depth data from this tag. Although the fishing and handling techniques replicated 'best practice' recreational fishing methods, the additional processing, including drawing blood samples and application of tags may bias the post-release survival estimate downward.

Factors related to the capture of the fish, physiological stress imparted during capture and handling duration (time out of water) were modelled against post-release fate using a GAM with a binomial error term. The initial, full factorial model was:

$$Fate = a + s_{FL}(FL) + s_{AD}(AD) + s_{SST}(SST) + BL + s_{Glu}(Glu) + s_{pH}(pH) + s_{Lac}(Lac) + s_{Cor}(Cor) + s_{Osm}(Osm) + s_{HT}(HT) + RL + \in$$

where *α* is the GAM intercept, *FL* is fork length, *AD* is angling duration, *SST* is sea surface temperature, *BL* is the ordinal severity of bleeding index, *Glu* is plasma glucose, *pH* is plasma pH, *Lac* is plasma lactate, *Cor* is plasma cortisol, *Osm* is plasma osmolarity, *HT* is handling time, *RL* is the ordinal release condition index, *ε* is a binomial error term and *s* is a thin-plate spline smoother. The same process of identifying collinearity and stepwise backward selection described previously was applied to identify the best candidate model.

Two fish were observed to be predated on immediately post-release. These fish were removed from this predictive analysis, although included in the post-release survival estimates. It was assumed that these fish did not die because of factors tested in this model.

Results

A total of 233 fish were landed during the study ranging in length from 78 – 188 cm FL, with a median size of 98 cm FL, excluding five large fish. The five large fish were caught adjacent to Victoria (187 cm FL) and Tasmania (162, 172, 184 and 188 cm FL). Six fish (3%) were landed either dead or in a non-responsive state with this fate attributed directly to the capture event. Deep hooking, leading to gill damage accounted for five of these cases. The other fish became tail wrapped towards the end of an extended angling duration, leading to the fish being retrieved tail-first to the boat.

In three cases, blood samples could not successfully be drawn from satellite tagged fish due to adverse weather conditions and/or the behaviour of the fish. While no blood was taken from these fish an attempt was made, including the insertion of a needle. The assumption was made that this constitutes a standardisation of method, but due to limited sample size we were unable to test whether the process of sampling blood affected survival. In other cases, there was an insufficient amount of blood plasma available to analyse several of the biochemical variables. Cortisol levels were not obtained for 12 tagged fish. Osmolarity and pH were not obtained for eight of these fish.

Post-release survival

Sixteen of the 59 satellite tagged fish were determined to have died during the period they had tags attached, 11 of which were attributed to the catch and release event. Four mortalities were considered natural, occurring greater than 19-days after release (Fig. 3). One individual was recaptured by a commercial longline vessel less than 24-hrs after release. It was categorised as not dying due to the recreational catch and release event, as taking a baited hook was evidence of feeding behaviour. It was assumed that this reflects that the fish was not significantly stressed or injured at the time of recapture.

Seven fish (63% of mortalities associated with the recreational fishing event) died within 24 hours of release (Table 1). Four of these fish were classified as direct catch-induced mortalities, one was inferred as a post-release predation based on dive and temperature data recorded by the tag and two were observed post-release predation by seals (Tables 1 & 2).

The post-release survival (PRS) rate of fish caught on lures rigged with J-hook, excluding the two fish that were observed to be predated upon immediately once they were returned to the water, was 86.6% (95% CI: 77.3 – 95.5%, $n = 44$). For fish caught with circle hooks the PRS rate was 87.4% (95% CI: 70 – 100%, $n = 8$), and for fish caught on lures with treble hooks the PRS rate was 60% (95% CI: 20 – 100%, $n = 5$). As the PRS rates of fish caught with J-hooks and circle hooks were similar, these categories were combined to increase sample size. The resulting PRS rate, with the inclusion of the two fish that were observed to be predated on, was 83.0% (95% CI: 75.9 – 90.7%, $n = 54$). Given the PRS rate of fish caught using lures with treble hooks was much lower, these individuals were not pooled with the other two hook categories. Noting however, that the sample size of treble hooked fish is low and the result is therefore indicative rather than statistically robust.

No explanatory variables were identified as significantly related to post-release survival by GAMs. A visual inspection of the relationships between angling duration, fish length, SST and each biochemical variable confirmed no obvious differences between fish that were classified as 'survived' or 'died' (Fig. 4).

Physiological stress

Plasma cortisol, lactate, and osmolarity levels were all identified to be significantly affected by angling duration (Table 3). The response of each of the significant biochemical variables increased with angling duration, the rate of increase however reduced for angling durations greater than approximately 15 minutes (Fig. 4). Sea surface temperature at the location of capture was significantly related to the response of glucose and lactate in blood plasma and fish size was significantly related to lactate response (Table 3). pH was not related to any factors tested.

Several biochemical variables were significantly correlated. Lactate was significantly correlated with all other biochemical variables with the strongest correlation identified with cortisol (r = 0.49). Cortisol was also significantly correlated with glucose (r = 0.27) and osmolarity (r = 0.46).

Discussion

Post-release survival

This is the first study to assess the survival rate of recreationally caught SBT after release. The reported post-release survival estimate should be considered conservative as the effects of processing, in particular drawing blood samples and attaching satellite tags are unknown and may have biased the results towards a higher mortality rate (Cooke and Schramm 2007). With the exception of hook type, no other factors tested were found to significantly influence the post-release survival rate. Therefore, the survival estimate is representative of a broad range of recreational fishing activities which differ by factors such as size distribution of fish caught, angling duration or sea surface temperature. Fish caught on lures configured with treble hooks had a lower post-release survival rate than fish caught on either baited circle hooks or lures configured with J-hooks. Given the low sample size of fish caught on treble hooks, however, it was not possible to determine if this result was significant. Different hook types have been shown to significantly influence post-release survival for other species (Skomal et al. 2002; Horodysky and Graves 2005), and as such further research into the effects of treble hooks on the post-release survival of SBT is warranted.

There have been no comprehensive studies to date on the national recreational harvest, or release rates, of SBT within Australia. However, two studies have been conducted that provide estimates of harvest and release rates from the recreational SBT fishery at a state level. The first was conducted in 2011 in Victoria (Green et al. 2012). Using a comprehensive onsite creel method, the recreational harvest of SBT was estimated at 240 t and the release rate reported as 25%, which equates to approximately 42 t assuming released fish had the same size composition as retained fish. By applying a post-release mortality rate (19%, all hook methods combined in lieu of no information on the proportion of fish caught by each hook type) an estimated 7.8 t were lost as post-release mortality from the Victorian recreational fishery in 2011. The second survey was conducted in 2012 using an offsite longitudinal phone-diary survey in Tasmania (Tracey et al. 2013). A total harvest of 79 t was estimated and a release rate of 24%. Applying the same principals as for the Victorian survey this equates to 14 t of fish released with 2.6 t lost to post-release mortality. These estimates indicate that post-release mortality of SBT adds approximately 3% to the total recreational harvest as unaccounted mortality and that this additional tonnage is insignificant relative to the Australian allocation of the TAC (5,193 t in 2014).

Previous studies on recreationally caught Atlantic bluefin tuna, *Thunnus thynnus* (ABT) have reported post-release survival rates of 100% for juveniles (Marcek and Graves 2014) and 94-97% for adults (Stokesbury et al. 2011). While the estimates presented for SBT are lower than the estimates presented for ABT, they are similar to those presented for other large pelagic fishes caught by recreational fishing methods, including white marlin *Tetrapturus albidus* (82.5%) (Horodysky and Graves 2005), black marlin *Istiompax indica* (89%) (Musyl et al. 2015), Sailfish *Istiophorus platypterus* (91.8%) (Musyl et al. 2015), and striped marlin *Kajikia audax* (74%) (Domeier et al. 2003).

The majority of SBT that were attributed to have died due to the capture process occurred within 24-hours after release (64%). This is also consistent with other studies on large pelagics showing mortality occurring shortly after release (Domeier et al. 2003; Horodysky and Graves 2005; Kerstetter and Graves 2006; Kerstetter and Graves 2008).

Predation of released fish by Australian fur seals *Arctocephalus pusillus* was observed on two occasions. On both occasions the seals interacted with the fish prior to landing (seals chased the fish while they were being retrieved to the boat – inflicting minor superficial grazing), and even though efforts were made to move on from the area before releasing the fish, the seals chased the boat and re-engaged with the fish. Direct observation of predation on fish after release has been reported in other studies (Danylchuk et al. 2007). Although, due to the logistics of observing fish for an extended period post-release, predation events are more commonly identified from data recorded on the PAT tags. The depth, temperature and light level data often reveal clear evidence of a predatory event, and in some cases, the data can provide insight into the predator's taxa or even species (Kerstetter et al. 2004; Beguer-Pon 2012; Marcek and Graves 2014).

In this study the satellite tags indicated predatory events occurred on six individuals. Two tags recorded temperatures of approximately 38°C, typical of the body temperature of a mammal, in this case most probably a seal (Austin et al. 2006). The temperature increases were concurrent with reduced light levels.

Four tags, two within 10-days post-release and two well after release, indicated an abrupt increase in temperature to approximately 26°C, 6 – 8°C above the ambient water temperature recorded prior to the predation event (Fig 2C). These events were also concurrent with a sustained drop in light level. The most likely candidate predator was Lamnid sharks, specifically Shortfin Mako (*Isurus oxyrinchus*), which are commonly found in the offshore waters adjacent to NSW and the east coast of Tasmania where these predatory events occurred. These shark species tend to maintain body temperatures 7–10°C above ambient (Carey and Teal 1969). The recorded depth profiles during the period when the tags were ingested were also consistent with the behaviour of Lamnid shark (Sepulveda et al. 2004).

In addition to the fish determined to have died as a response to being captured, four PAT tagged fish were assessed to have died due to natural causes. Natural mortality estimates for SBT are non-linear and age dependent, with higher mortality rates for young fish, ranging from 0.20 – 0.42 yr^{-1} (CCSBT 2009). Given these relatively high rates some degree of natural mortality during this study was not unexpected with tags programmed to detach six months after deployment.

Physiological stress

Cortisol is considered to be the best quantitative indicator of physiological stress (Ellis et al. 2007) and responds to a variety of both acute and chronic stressors (Pickering 1992; Barton 2000). Chronically elevated levels are often associated with adverse consequences such as reduced growth rate (Jentoft et al. 2005) and immune-suppression (Watanuki et al. 2002) as it shifts energy investment from anabolic to catabolic activities, such as energy mobilisation and maintenance of homeostasis (Bonga 1997).

In this study, a typical stress response was observed in relation to angling duration. Plasma cortisol concentrations from SBT were elevated and sharply increased in association with angling duration with peak levels observed within 10-30 mins, although cortisol concentrations will likely increase post-release as values do not typically peak until 1-2 hours following exercise (Barton et al. 2002). Plasma glucose and lactate concentrations followed a similar pattern and were significantly associated with cortisol and angling duration, concurring with other studies (Gustaveson et al. 1991).

Longer angling durations have been shown in many studies to increase physiological disturbance and the time required for recovery (Cooke and Suski 2005; Cooke et al. 2008), however, several studies have found no relationship between angling duration and post-release mortality (Diodati and Richards 1996), including species such as, rainbow trout, *Salmo trutta* (Schisler and Bergersen 1996) and striped marlin (Domeier et al. 2003). The results here do not indicate that angling duration effects survival of SBT. Extended angling durations do, however, increase the physiological effect on the fish. Hence consideration should be given to using appropriate fishing tackle relative to the size of the fish to minimise the angling duration, subsequently improving the welfare of the animal (Cooke and Suski 2005; Iwama 2007).

Water temperature at the location of capture was not related to the fate of SBT post-release. This is not surprising given the broad thermal niche of the species. Satellite tags indicated that the fish spent time in water ranging from 8 - 22°C normally distributed around a mean of 16°C. The ability of Bluefin tuna to tolerate such a wide range of temperatures is due to their endothermic physiology, whereby they can retain metabolic heat.

Hooking location has been reported as the single most important factor related to a fish's fate as a result of recreational capture (Bartholomew and Bohnsack 2005). When fish are deep hooked they tend to experience increased bleeding and damage to vital organs (Lyle et al. 2007). This often equates to high rates of immediate and short-term mortality (Bartholomew and Bohnsack 2005; Cooke and Suski 2005; Arlinghaus et al. 2007; Lyle et al. 2007). Seven of the 59 fish satellite tagged in this study were caught using baited circle hooks while drifting over schools of SBT. Six of these fish were hooked in the corner of the mouth and one was deep hooked, in the latter case the fishing line was cut and the hook left in the fish, this fish survived post-release. This practice has been shown to reduce mortality rates relative to removing the hook, with the fish eventually shedding the hook (Schill 1996; Tsuboi et al. 2006; Lyle et al. 2007).

In this study 59% of the SBT that had PAT tags attached were identified as having little to no bleeding, 37% had minor bleeding associated with the hooking location in the mouth and 2% had major bleeding, one around the mouth and the other due to major external damage ventral to the operculum from a treble hook. Blood loss due to hooking damage, however, was not significantly related to the fate of the fish post-release. One fish that died within 10-days post-release had minor internal bleeding from the gill region inflicted by a treble hook and was predated upon within hours after release. The two fish that were recorded as having major bleeds both survived. There are many instances where injuries include minor or moderate bleeding that is unlikely to result in mortality (Arlinghaus et al. 2007).

These results indicate that voluntary catch-and-release fishing as well as release due to catch limit regulation, are not a significant source of mortality based on current estimates of recreational release rates of SBT. It should be noted however that if either the harvest rate or the release rate were to increase the absolute tonnage lost through post-release mortality will also increase. Recent management regulations in New South Wales have reduced the bag limit from two to one fish per person, and a boat limit of four fish has recently been implemented in Tasmania, both of which may lead to increased release rates. As the population of SBT rebuilds it is also expected that effort and subsequent harvest from the recreational fishery will increase.

While the post-release mortality rate was relatively low, there was evidence of adverse physiological response to capture, and although this was not found to relate to survival in this study, maintaining or improving fish handling practices is fundamental to minimising the unintended impacts of recreational fishing on SBT. This, in turn, will improve animal welfare and stewardship by the recreational fishing sector. The results presented here, in concert with estimates of recreational harvest for which methods are currently being developed, will provide greater transparency of an unaccounted source of mortality. Subsequently these results will improve the completeness of data available for stock assessment to facilitate effective international management strategies aimed at continuing to rebuild the southern bluefin tuna population.

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References

Arlinghaus, R., Cooke, S.J., Lyman, J., Policansky, D., Schwab, A., Suski, C., Sutton, S.G., and Thorstad, E.B. 2007. Understanding the complexity of catch-and-release in recreational fishing: an integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. Rev. Fish. Sci. **15**(1-2): 75-167.

Arlinghaus, R., Klefoth, T., Cooke, S.J., Gingerich, A., and Suski, C. 2009. Physiological and behavioural consequences of catch-and-release angling on northern pike (*Esox lucius* L.). Fish. Res. **97**(3): 223-233.

Austin, D., Bowen, W., McMillan, J., and Boness, D. 2006. Stomach temperature telemetry reveals temporal patterns of foraging success in a free-ranging marine mammal. Anim. Ecol. **75**: 408-420.

Bartholomew, A., and Bohnsack, J.A. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Rev. Fish Biol. Fish. **15**(1-2): 129-154.

Barton, B.A. 2000. Salmonid fishes differ in their cortisol and glucose responses to handling and transport stress. N. Am. J. Aquac. **62**(1): 12-18.

Barton, B.A., Morgan, J.D., and Vijayan, M.M. 2002. Physiological condition-related indicators of environmental stress in fish. *In* Biological Indicators of Aquatic Ecosystem Stress. *Edited by* S.M. Adams. American Fisheries Society, Bethesda, MD. pp. 111-148.

Béguer-Pon, M., Benchetrit, J., Castonguay, M., Aarestrup, K., Campana, S.E., Stokesbury, M.J.W., Dodson, J.J. 2012. Shark Predation on Migrating Adult American Eels (*Anguilla rostrata*) in the Gulf of St. Lawrence. PLoS ONE 7(10): e46830.

Bonga, S.W. 1997. The stress response in fish. Physiol. Rev. **77**(3): 591-625.

Carey, F., and Teal, J. 1969. Mako and porbeagle: warm-bodied sharks. Comp. Biochem. Physiol. Part A **28**: 199-204.

CCSBT. 2009. Report of the Fourteenth Meeting of the Scientific Committee. CCSBT, Busan, Korea.

CCSBT. 2014. Report of the extended scientific committee for the nineteenth meeting of the scientific committee. Commission for the Conservation of Southern Bluefin Tuna (CCSBT).

Cooke, S., and Schramm, H. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. Fish. Manag. Ecol. **14**(2): 73-79.

Cooke, S., Suski, C., Danylchuk, S., Danylchuk, A., Donaldson, M., Pullen, C., Bulté, G., O'toole, A., Murchie, K., and Koppelman, J. 2008. Effects of different capture techniques on the physiological condition of bonefish *Albula vulpes* evaluated using field diagnostic tools. J. Fish Biol. **73**(6): 1351-1375.

Cooke, S.J., Schreer, J.F., Dunmall, K.M., and Philipp, D.P. 2012. Strategies for quantifying sub-lethal effects of marine catch-and-release angling: insights from novel freshwater applications, American Fisheries Society, pp. 121-134.

Cooke, S.J., and Suski, C.D. 2005. Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? Biodiv. Cons. **14**(5): 1195-1209.

Danylchuk, S.E., Danylchuk, A.J., Cooke, S.J., Goldberg, T.L., Koppelman, J., and Philipp, D.P. 2007. Effects of recreational angling on the post-release behavior and predation of bonefish (*Albula vulpes*): The role of equilibrium status at the time of release. J. Exp. Mar. Biol. Ecol. **346**(1): 127-133.

Diodati, P.J., and Richards, A. 1996. Mortality of striped bass hooked and released in salt water. Trans. Am. Fish. Soc. **125**: 300-307.

Domeier, M.L., Dewar, H., and Nasby-Lucas, N. 2003. Mortality rate of striped marlin (*Tetrapturus audax*) caught with recreational tackle. Mar. Freshw. Res. **54**(4): 435-445.

Donaldson, M.R., Arlinghaus, R., Hanson, K., and J., C.S. 2008. Enhancing catch-and-release science with biotelemetry. Fish Fish. **9**: 79-105.

Ellis, T., James, J., Sundh, H., Fridell, F., Sundell, K., and Scott, A. 2007. Non-invasive measurement of cortisol and melatonin in tanks stocked with seawater Atlantic salmon. Aquaculture **272**(1): 698-706.

Goodyear, C.P. 2002. Factors affecting robust estimates of the catch-and-release mortality using pop-up tag technology. *In* Catch and release in marine recreational fisheries, American Fisheries Society, Symposium 30. *Edited by* A. Studholme and J. Lucy, Bethesda, Maryland. pp. 172–179.

Graves, J.E., Luckhurst, B.E., and Prince, E.D. 2002. An evaluation of pop-up satellite tags for estimating postrelease survival of blue marlin (*Makaira nigricans*) from a recreational fishery. Fish. Bull. **100**: 134-142.

Green, C., Brown, P., Giri, K., Bell, J., and Conron, S. 2012. Quantifying the recreational catch of southern bluefin tuna off the Victorian coast., Department of Primary Industries, Victoria.

Gustaveson, A.W., Wydoski, R.S., and Wedemeyer, G.A. 1991. Physiological response of largemouth bass to angling stress. Trans. Am. Fish. Soc. **120**(5): 629-636.

Horodysky, A.Z., and Graves, J.E. 2005. Application of pop-up satellite tag technology to estimate postrelease survival of white marlin (*Tetrapterus albidus*) caught on circle and straight-shank “J”) hooks in the western North Atlantic recreational fishery. Fish. Bull. **103**(1): 84-96.

Iwama, G.K. 2007. The welfare of fish. Dis. Aquat. Org. **75**: 155-158.

Jentoft, S., Aastveit, A.H., Torjesen, P.A., and Andersen, Ø. 2005. Effects of stress on growth, cortisol and glucose levels in non-domesticated Eurasian perch (*Perca fluviatilis*) and domesticated rainbow trout (*Oncorhynchus mykiss*). Comp. Biochem. Physiol. Part A **141**(3): 353-358.

Kerstetter, D.W., and Graves, J.E. 2006. Survival of white marlin (*Tetrapturus albidus*) released from commercial pelagic longline gear in the wester North Atlantic. Fish. Bull. **104**: 434-444.

Kerstetter, D.W., and Graves, J.E. 2008. Postrelease survival of Sailfish caught by commercial pelagic longline gear in the southern gulf of Mexico. N. Am. J. Fish. Manage. **28**: 1578-1586.

Kerstetter, D.W., Luckhurst, B.E., Prince, E.D., and Graves, J.E. 2003. Use of pop-up satellite archival tags to demonstrate survival of blue marlin (*Makaira nigricans*) released from pelagic longline gear. Fish. Bull. **101**: 939-948.

Kerstetter, D.W., Polovina. J.J., and J.E. Graves. 2004. Evidence of shark predation and scavenging on fishes equipped with pop-up satellite archival tags. Fish. Bull. **102:** 750–756.

Kohler, N.E., Casey, J.G., and Turner, P.A. 1998. NMFS Cooperative Tagging Program, 1962–1993: an atlas of shark tag and recapture data. Mar. Fish. Rev. **60**: 1–87.

Lyle, J.M., Moltschaniwskyj, N.A., Morton, A.J., Brown, I.W., and Mayer, D. 2007. Effects of hooking damge and hook type on post-release survival of sand flathead (*Platycephalus bassensis*). Mar. Freshw. Res. **58**(5): 445-453.

Marcek, B.J., and Graves, J.E. 2014. An Estimate of Postrelease Mortality of School-Size Bluefin Tuna in the U.S. Recreational Troll Fishery. N. Am. J. Fish Manage. **34**(3): 602-608.

Moyes, C.D., Fragoso, N., Musyl, M.K., and Brill, R.W. 2006. Predicting postrelease survival in large pelagic fish. Trans. Am. Fish Soc. **135**(5): 1389-1397.

Muoneke, M.I., and Childress, W.M. 1994. Hooking mortality: a review for recreational fisheries. Rev. Fish. Sci. **2**: 123-156.

Musyl, M.K., Moyes, C.D., Brill, R.W., Mourato, B.L., West, A., McNaughton, L.M., Wei-Chuan, C., and Chi-Lu, S. 2015. Postrelease mortality in istiophorid billfish. Can. J. Fish. Aquat. Sci. **72**: 1-19.

Pickering, A. 1992. Rainbow trout husbandry: management of the stress response. Aquaculture **100**(1): 125-139.

Plikaytis, B.D., Holder, P.F., Pais , L.B., Maslanka, S.E., Gheesling, L.L., and Carlone, G.M. 1994. Determination of parallelism and non parallelism in bioassay dilution curves. J. Clin. Microbiol. **32**: 2441-2447.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.

Schill, D.J. 1996. Hooking mortality of bait-caught Rainbow Trout in an Idaho trout stream and a hatchery: implications for special-regulation management. N. Am. J. Fish. Manage. **16**: 348-356.

Schisler, G.J., and Bergersen, E.P. 1996. Post release hooking mortality of Rainbow Trout caught on scented artificial baits. N. Am. J. Fish. Manage. **16**: 570-578.

Sepulveda, C., Kohin, S., Chan, C., Vetter, R., and Graham, J. 2004. Movement patterns, depth preferences, and stomach temperatures of free-swimming juvenile mako sharks, *Isurus oxyrinchus*, in the Southern California Bight. Mar. Biol. **145**: 191-199.

Skomal, G. 2007. Evaluating the physiological and physical consequences of capture on post-release survivorship in large pelagic fishes. Fish Manag. Ecol. **14**(2): 81-89.

Skomal, G.B., and Chase, B.C. 2002. The physiological effects of angling on post-release survivorship in tunas, sharks, and marlin, pp. 135-138.

Skomal, G.B., Chase, B.C., and Prince, E.D. 2002. A comparison of circle hook and straight hook performance in recreational fisheries for juvenile Atlantic bluefin tuna. *In* Catch and release in marine recreational fisheries. *Edited by* J.A. Lucy and A.L. Studholme. American Fisheries Society, Symposium 30, Bethesda, Maryland. pp 57-65.

Stokesbury, M.J.W., Neilson, J.D., Susko, E., and Cooke, S.J. 2011. Estimating mortality of Atlantic bluefin tuna (*Thunnus thynnus*) in an experimental recreational catch-and-release fishery. Biol. Conserv. **144**: 2684-2691.

Tetzlaff, J.C., Pine III, W.E., Allen, M.S., and Ahrens, R.N.M. 2013. Effectiveness of size limits and bag limits for managing recreational fisheries: A case study of the Gulf of Mexico recreational Gag Fishery. Bull. Mar. Sci. **89**(2): 483-502.

Tracey, S., Lyle, J., Ewing, G., Hartmann, K., and Mapleston, A. 2013. Offshore recreational fishing in Tasmania 2011/12. Institute for Marine and Antarctic Studies, Hobart, Tasmania.

Tsuboi, J., Morita, K., and Ikeda, H. 2006. Fate of deep-hooked white-spotted charr after cutting the line in a catch-and-release fishery. Fish. Res. **79**: 226-230.

Watanuki, H., Yamaguchi, T., and Sakai, M. 2002. Suppression in function of phagocytic cells in common carp *Cyprinus carpio* L. injected with estradiol, progesterone or 11-ketotestosterone. Comp.Biochem.Physiol. Part C **132**(4): 407-413.

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A., and Smith, G. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, New York.

Zuur, A.F., Ieno, E.N., and Elphick, C.S. 2010. A protocol for data exploration to avoid common statistical problems. Meth.Ecol.Evol. **1**: 3-14.

TABLES

Table 1. The number of fish identified as not surviving after release (up to 10-days). Fish caught on J-hooks (J) and circle hooks (C) are combined as the PRS rates were similar. Fish caught on treble hooks (T) are reported separately as the PRS was much lower than for the other two hook categories. Noting however, that the sample size of fish caught on treble hooks (*n* = 5) was small, therefore this result is indicative.

Day of mortality post-release	Moribund		Predation		Total died		Cumulative number died		PRS (%)	
	J & C	T	J & C	T	J & C	T	J & C	T	J & C	T
1	4	0	2	1	6	1	6	1	88.9	80.0
3	0	0	1	0	1	0	7	1	87.0	80.0
5	1	0	0	0	1	0	8	1	85.2	80.0
8	0	1	0	0	0	1	8	2	85.2	60.0
10	0	0	1	0	1	0	9	2	83.3	60.0

Table 2. Fate of the 59 fish fitted with PAT tags. Mortalities occurring within 10-days post-release were attributed to the capture event (PRM_{CI}), with the exception of a recapture. Mortalities occurring 10-days or more post-release were considered natural (PRM_N).

Fate description	No. of fish (≤ 10 days)	No. of fish (> 10 days)
PRM_{CI} - Early onset catch induced	4	-
PRM_{CI} - Delayed onset catch induced	2	-
PRM_{CI} - Catch induced post-release predation	3	-
PRM_{CI} - Observed post-release predation	2	-
PRM_N - Natural mortality	-	2
PRM_N – Natural predation	-	2
PRM_R – Recapture	1	-
PRS – Premature tag shedding	-	31
PRS – Full term	-	12

Table 3. The results of generalised additive modeling between the suite of biochemical indicators and angling duration (*AD*), fork length (*FL*), sea surface temperature (*SST*) and an ordinal blood loss index (*BL*). The full initial model was $y \sim s_{AD}(AD)+s_{FL}(FL)+s_{SST}(SST)+BL$. The model was reduced for each response variable using a backwards stepwise process. The significant explanatory variables for each reduced model are shown for each response variable.

Response variable (*y*)	Explanatory variables	n	*GCV*	*F*	*P*	R^2 *adj*	*Deviance explained*	*Error family(link)*
Glucose (mmol/L)		262	1.09			0.05	6.5%	Gaussian (identity)
	s(*FL*)			4.68	**0.009**			
	s(*SST*)			2.69	0.048			
Lactate (mmol/L)		262	15.15			0.36	37.4%	Gaussian (identity)
	s(*AD*)			42.97	**<0.001**			
	s(*FL*)			7.90	**<0.001**			
	s(*SST*)			6.11	**0.014**			
Cortisol (ng/ml)		177	2237.70			0.58	58.9%	Gaussian (identity)
	s(*AD*)			50.0	**<0.001**			
Osmolarity (Osml/L)		180	0.004			0.27	29.9%	Gamma(log)
	s(*AD*)			22.51	**<0.001**			

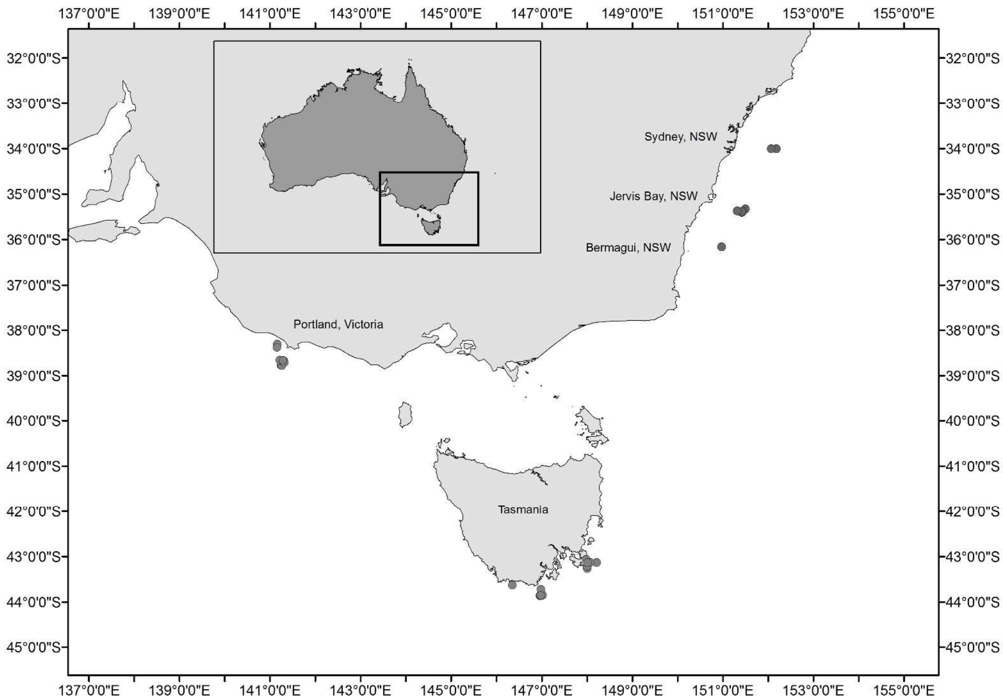

Fig. 1. Capture and release locations (grey circles) of satellite tagged southern bluefin tuna caught using recreational fishing methods around southeast Australia, including Tasmania.

297x209mm (300 x 300 DPI)

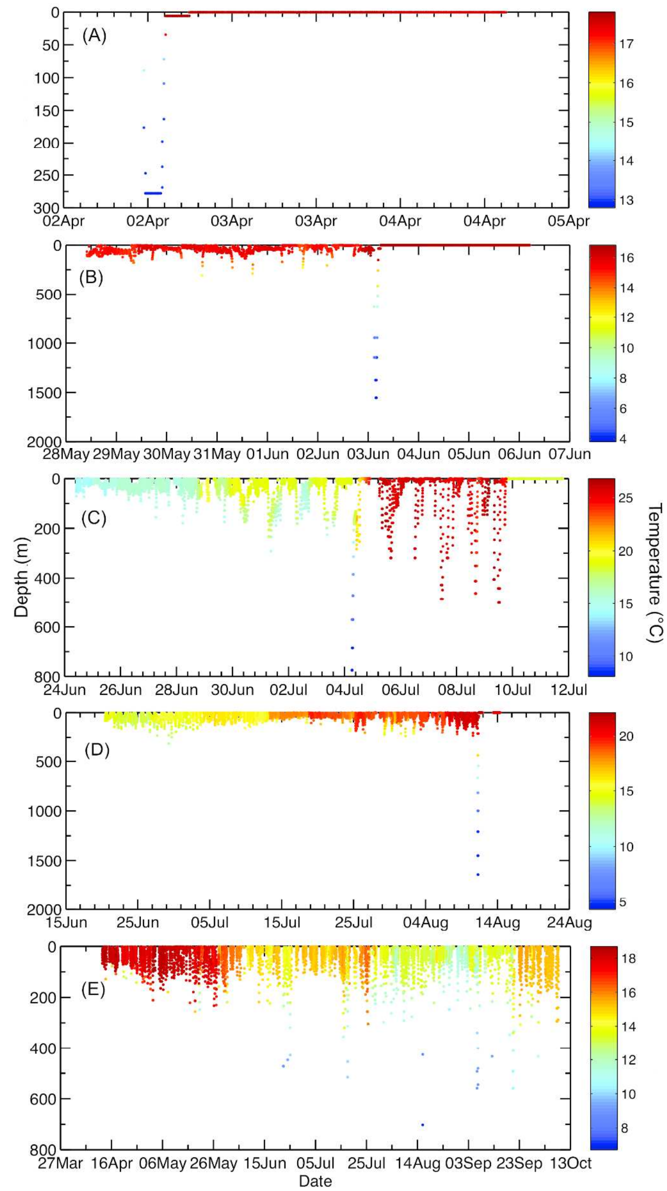

Fig. 2. PAT tag data illustrating different fates of fish post release. (A) Early onset catch induced post-release mortality, occurring within 24-hours after release. (B) Delayed onset catch induced post-release mortality, occurring within 10-days after release. (C) Catch induced post-release predation, indicated by rapid increase in temperature. (D) Natural mortality, occurring later than 10-days post-release. (E) Survival full term deployment (180 days).

154x276mm (300 x 300 DPI)

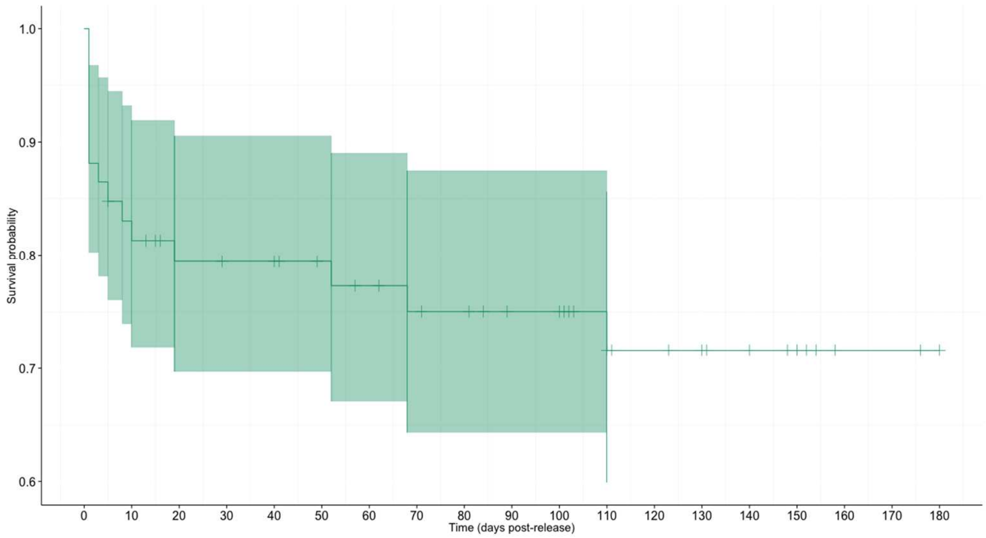

Fig. 3. The proportion of southern bluefin tuna surviving on each day post release as estimated using a Kaplan-Meier survival function (n = 59). The shaded area indicates the 95% confidence intervals. The small vertical lines on the plot indicate premature tag shedding.

463x263mm (72 x 72 DPI)

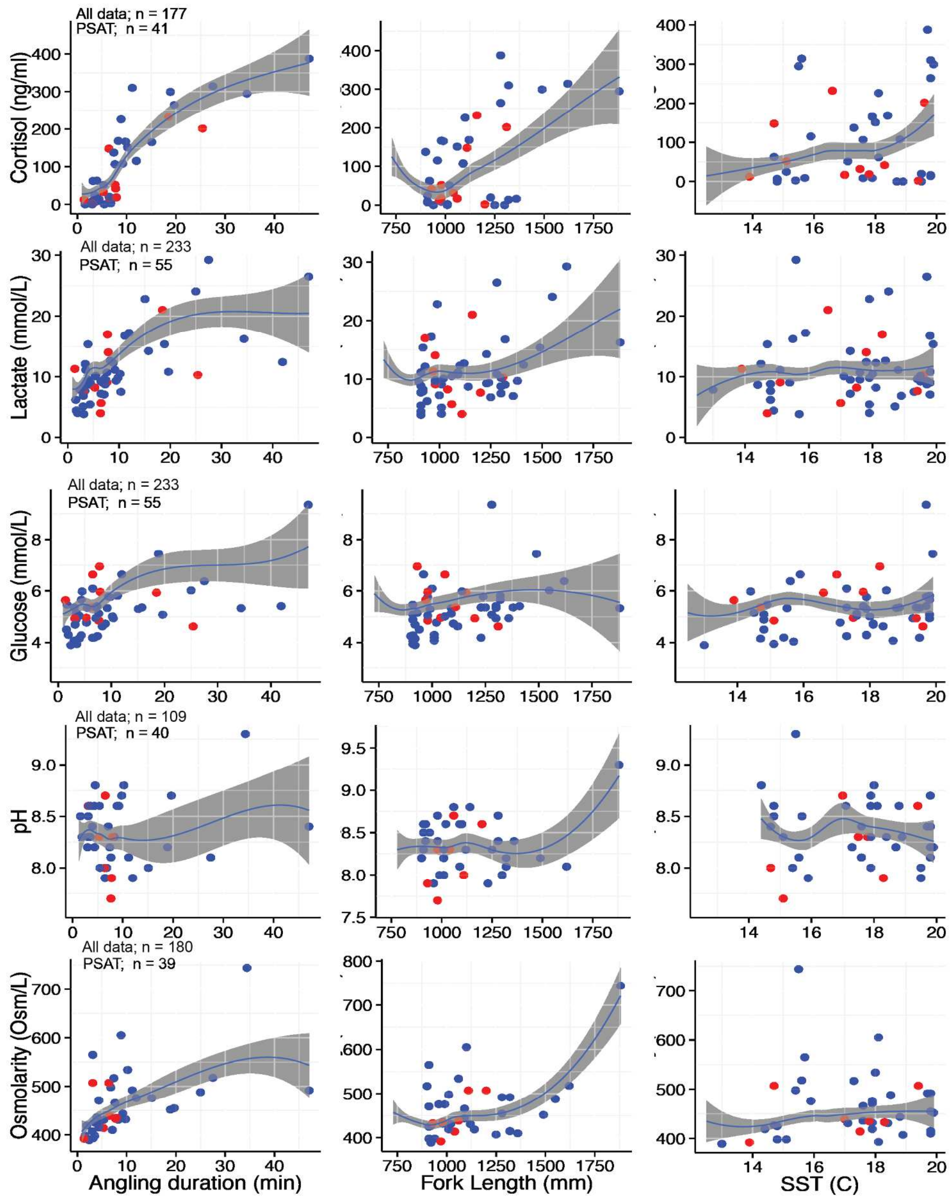

Fig. 4. Response of biochemical blood plasma variables to angling duration, fish length (FL) and SST. The fitted line is a LOESS smoother applied to all available data and the grey shading illustrates the 95% confidence intervals of the smoother fit. Blue points indicate southern bluefin tuna (SBT) that were PAT tagged and survived greater than 10-days after release, red points indicate SBT that were PAT tagged and did not survive to 10-days after release. Data points from SBT that were not tagged have been removed to aid the visualisation of biochemical values of the tagged fish against the expected fits to all data.

Table S1. Details of satellite tagged southern bluefin tuna. Deployment details include release date and location, fish length and programmed detachment day. Pop-up transmission data includes the date and location that the tag released from the fish as well as the number of days each tag was attached.

Releases							Pop-up transmission			
Tag	Location	Date	Latitude	Longitude	LCF (cm)	Programmed duration (d)	Date	Latitude	Longitude	Actual duration (d)
2012										
115746	TAS	16/05/2012	-43.22	148.01	91	40	3/06/2012	-44.38	149.27	18
115748	TAS	16/05/2012	-43.22	148.01	91	40	26/06/2012	-37.60	139.20	40
115743	TAS	11/06/2012	-43.63	146.36	93	40	23/07/2012	-38.43	139.62	40
115749	NSW	23/06/2012	-36.17	150.97	123	100	3/10/2012	-36.18	158.75	100
115750	NSW	23/06/2012	-36.17	150.97	100	100	2/10/2012	-41.81	149.10	100
2013										
121772	TAS	4/03/2013	-43.85	147.00	109	180	31/08/2013	-43.86	150.77	180
121774	TAS	4/03/2013	-43.86	147.01	106	180	8/04/2013	-44.44	148.91	35
121776	TAS	4/03/2013	-43.86	146.97	116	180	9/03/2013	-43.84	146.91	5
121777	TAS	4/03/2013	-43.85	147.01	123	180	31/08/2013	-36.07	151.96	180
121780	TAS	4/03/2013	-43.85	147.00	112	180	27/08/2013	-39.17	152.72	176
115742	VIC	10/04/2013	-38.78	141.25	109	180	9/05/2013	-39.27	142.42	29
115745	VIC	10/04/2013	-38.78	141.25	101	180	7/10/2013	-38.77	135.60	180
115751	VIC	10/04/2013	-38.78	141.25	110	180	16/09/2013	-41.49	149.45	159
121778	VIC	10/04/2013	-38.78	141.26	106	180	9/10/2013	-35.78	122.66	180
128677	VIC	11/04/2013	-38.66	141.22	91	180	4/07/2013	-39.85	143.10	84
121775	TAS	1/05/2013	-43.13	148.05	188	180	27/06/2013	-39.04	149.17	57
128666	TAS	1/05/2013	-43.13	148.05	102	180	29/10/2013	-42.43	150.47	180
121842	VIC	10/05/2013	-38.31	141.16	90	180	5/10/2013	-36.06	137.64	148
128691	VIC	10/05/2013	-38.42	141.31	93	180	15/05/2013	-38.68	142.96	5
128697	VIC	10/05/2013	-38.38	141.15	92	180	19/06/2013	-38.11	140.77	40
128689	TAS	18/05/2013	-43.12	148.07	184	180	21/05/2013	-43.19	148.11	3
128694	TAS	18/05/2013	-43.13	148.07	162	180	5/10/2013	-39.13	152.19	140
121779	TAS	19/05/2013	-43.26	148.01	111	180	1/06/2013	-43.87	148.04	13
115744	TAS	28/05/2013	-43.86	146.96	101	180	18/08/2013	-37.15	153.21	82
121773	TAS	28/05/2013	-43.86	146.98	98	180	6/06/2013	-40.52	150.76	9
121781	TAS	29/05/2013	-43.13	148.22	91	180	26/10/2013	-38.20	151.31	150
115747	TAS	20/06/2013	-43.83	147.01	91	180	15/08/2013	-31.23	154.76	56
128671	TAS	20/06/2013	-43.73	146.98	92	180	1/11/2013	-40.67	144.53	134
128674	TAS	20/06/2013	-43.86	146.98	94	180	21/08/2013	-41.15	150.41	62
128665	TAS	21/06/2013	-43.85	147.02	91	180	6/07/2013	-43.14	145.69	15
128664	NSW	28/06/2013	-35.34	151.50	149	180	24/10/2013	-38.23	154.23	118
128670	NSW	28/06/2013	-35.38	151.45	135	180	4/10/2013	-41.92	151.10	98

128667	NSW	29/06/2013	-35.39	151.42	131	180	29/07/2013	-35.02	151.13	30
128679	NSW	29/06/2013	-35.39	151.42	130	180	4/12/2013	-41.65	156.70	158
128680	NSW	29/06/2013	-35.39	151.42	136	180	20/10/2013	-43.78	153.52	113
128682	NSW	29/06/2013	-35.41	151.42	132	180	4/07/2013	-32.17	152.50	5
128692	NSW	29/06/2013	-35.39	151.42	128	180	13/11/2013	-43.01	149.10	137
128695	NSW	29/06/2013	-35.41	151.42	132	180	23/10/2013	-38.86	160.32	116
128698	NSW	29/06/2013	-35.39	151.42	128	180	17/10/2013	-43.99	145.84	110
128672	NSW	12/07/2013	-34.01	152.18	138	180	21/12/2013	-44.15	146.71	162
128675	NSW	12/07/2013	-34.01	152.18	130	180	9/12/2013	-46.66	166.64	150
128678	NSW	12/07/2013	-34.01	152.18	130	180	1/10/2013	-35.79	166.46	81
128681	NSW	12/07/2013	-34.01	152.18	124	180	13/11/2013	-42.10	148.34	124
128688	NSW	12/07/2013	-34.01	152.18	120	180	23/07/2013	-34.94	151.09	11
128699	NSW	12/07/2013	-34.01	152.18	125	180	8/11/2013	-39.37	166.63	119
2014										
128669	VIC	2/04/2014	-38.68	141.31	104	180	4/04/2014	-38.67	141.32	2
128676	VIC	2/04/2014	-38.68	141.31	98	180	14/05/2014	-40.05	143.32	42
128685	VIC	2/04/2014	-38.67	141.28	99	180	10/05/2014	-38.64	140.55	38
128686	VIC	2/04/2014	-38.67	141.28	98	180	4/04/2014	-38.62	141.48	2
128696	VIC	2/04/2014	-38.67	141.28	101	180	10/06/2014	-38.37	140.82	69
128684	VIC	3/04/2014	-38.72	141.32	98	180	30/09/2014	-36.98	124.13	180
128683	TAS	27/04/2014	-43.07	147.98	96	180	10/05/2014	-43.0	147.4	13
128668	TAS	8/05/2014	-43.86	146.97	114	180	12/08/2014	-39.4	143.2	96
12868301	TAS	24/06/2014	-43.13	148.01	97	70	4/07/2014	-40.3	150.0	10
128690	TAS	14/07/2014	-43.22	148.01	92	180	11/01/2015	-43.22	148.01	180
133520	NSW	23/07/2014	-34.00	152.07	155	180	27/11/2015	-42.80	152.16	130
128693	NSW	25/07/2014	-35.38	151.32	141	180	12/09/2015	-35.64	160.67	49
133519	NSW	25/07/2014	-35.38	151.32	120	180	05/11/2105	-42.99	154.46	103
133521	NSW	25/07/2014	-35.38	151.32	131	180	19/01/2015	-41.51	168.90	180