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Summary of Observer Data on Composition and Life-status of Fishes Caught in the Eastern Tuna and Billfish Fishery

Information Report to the 5th meeting of the CCSBT Ecologically Related Species Working Group

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Abstract.—The Eastern Tuna and Billfish Fishery was evaluated by an observer program in the 2001 and 2002 season. This report summarizes data on species composition and life status of 8,695 fish caught in the longline fishery. Tuna (6 species) comprised 69% of the catch, billfish (4 species) 4%, sharks and rays (16 species) 4%, and other fishes (17 species) comprised another 23% of the catch. The life status of the catch was categorized as alive-vigorous (40% all species combined), alive-sluggish (8%), alive-just (12%), and dead (40%). The smallest species of tuna (<100 cm fork length: albacore tuna and skipjack tuna) had low proportions of live catch, while larger species (>100 cm fork length: yellowfin tuna, bigeye tuna, and SBT) had relatively high proportions. Within tuna species, the relationship between length and proportion of live catch was both positive and negative depending on the species. Models of southern bluefin tuna life status for individual fish suggest that longer soak times, cooler water temperature and larger body size increase the probability of mortality.

INTRODUCTION

This work reports upon observer data on the catch and by-catch Australia's Eastern Tuna and Billfish Fishery (ET&BF). These results are part of a larger study that was initiated as a two-year project to assist in the evaluation of management procedures for the fishery, with specific objectives to (1) determine the level of southern bluefin tuna (SBT) by-catch taken by a range of long-lining vessels within the ET&BF over the June–September period in 2001 and 2002; (2) describe the extent to which by-catch of SBT by ET&BF longliners varies with geographical location, time, and targeting practices; (3) describe the life status of SBT caught by ET&BF longliners; and (4) using pop-up tags, determine the extent of post-release mortality in SBT caught and released by ET&BF longliners and examine influence of SBT life status and set time. Although the by-catch and life status of other species was not a specific objective of this study, these data were nonetheless collected and are briefly summarized here.

METHODS

Observer program and data.—Placement of observers on longline fishing vessels in the ET&BF first required the permission of vessel operators, many of which had concerns for confidentiality of data collected on their vessels. An agreement was reached whereby observers kept names of vessels and operators anonymous, and all data was signed-off by operators at the end of each observer trip. Observers were employed by CSIRO Marine Research (CMR) and the Australian Fisheries Management Authority (AFMA). Only CMR observers were deployed in 2001, and both CMR and AFMA observers were active in 2002.

Observers recorded location and time of set and haul operations, as well as sea surface temperature and sea conditions. Fishing practices of each set were described by number and depth of hooks, soak time (from start of set to end of haul), and nominated target species. CMR observers made additional observations of weather, target sea surface temperature, types of baits used, and distance and bearing to water temperature fronts. AFMA observers recorded the species name, length, and life status of each fish caught, however, under the confines of the confidentiality agreement CMR observers recorded this information only for the major target species of albacore tuna, bigeye tuna, broadbill swordfish, southern bluefin tuna, and yellowfin tuna. In office analyses, the weight of each SBT caught was estimated with the widely used length-weight relationships from Robins (1963) for fish <130 cm and Warashina and Hisada (1970) for fish >130 cm—as reported by Caton (1991).

Life status analyses.—The life status of fish caught by long line fishing was classified into three categories for dead fish (damaged, in rigor, or flexible) and three categories for live fish (just, sluggish, or vigorous). Because CMR observers only recorded this information for tunas and billfishes, we used only AFMA data (which was collected in 2002) to report general catch composition and life status.

We examined the effect of sea surface temperature (at start of set), soak time, number of hooks in set, and length of fish on SBT life status. Life status was considered by three different levels of aggregation (1) by all six categories; (2) by three categories (dead, intermediate alive, or vigorous alive); and (3) by two categories (dead or alive), and we used both CMR and AFMA data collected in 2001 and 2002. Box and whisker plots were used to examine single variable relationships, and multivariate relationships were explored using multinomial log-linear models that were fitted using neural-networks (Venables and Ripley 2002). The latter were used to predict the probability of a fish being in any one of the life status categories.

RESULTS

Observation effort.—The observation program was directed towards a 153 day (May–September) period. In 2001, however, negotiations with boat owners to place CMR observers on vessels were not concluded until two months into the 2001 fishing season, and only 32 days (21%) of this period was covered (all by CMR observers). In 2002 both AFMA and CMR observers were operating in 149 days (97%) of this period. A total of 20 longline sets on 4 boats were monitored in 2001, which represented 11% of the total effort of the fleet that was overlapping with the observation area and time period (Table 1). In 2002 a total of 212 longline sets on 36 boats were observed, which represented 17% of the fleet effort. Observer effort over the two years of sampling ranged between latitude 29.5^{o} S and 39.8^{o} S, but was concentrated in a region bounded in the south by the area of greatest SBT catch, near 35^{o} S and in the north by latitude 30^{o} S (Fig. 1).

Catch composition.—Observers recorded 54 fish species, 4 sea bird species and one species of turtle in the longline catch (Table 2). There were 6 species of tuna, 4 of billfish, 16 of shark, and 17 species of other fishes. Tunas made up 69% of the catch, billfishes 4%, sharks 4%, and other fishes 23%. There were also 12 sea birds (3 species) and 1 turtle reported in the longline catch. Yellowfin tuna accounted for the majority (39%), followed by albacore tuna (15%), black oilfish (9%), and SBT (6%).

Life status of all fishes.—Table 3 is a summary of only the AFMA data set for life status of all fishes, since CMR observers only recorded information for commercial speciers. In considering the life status of all fishes combined, there was an equal split between the proportions of those caught dead and those caught in an alive-vigorous condition (Table 3). Shark species generally had high proportions of alive-vigorous catch where there were ten or more catch records. Of the other fishes category (with 10 or more records), the greatest proportion of dead catch was recorded for barracouta (80%), followed by long nosed lancetfish (68%) and snake mackerel (67%). Relatively high proportions of alive-vigorous catch were recorded for sunfish (80%) and dolphinfish (71%). Of billfishes, the lowest proportion of dead catch (21%) was in blue marlin and the highest proportion was in broadbill swordfish (54%). Seabirds appeared to suffer a high level of mortality when caught by the long line gear (92% for the 11 records of all seabirds combined).

In tunas there was a wide variation (29% to 88%) in proportions of dead catch, but there was a general split between species with high and low proportions of dead catch. Albacore tuna, mackerel tuna, and skipjack tuna had the highest proportions of dead catch, while bigeye tuna, SBT, and yellowfin tuna had relatively low proportions of dead catch. These differences in proportion appear to be related to the average size of species (Fig. 2*a*), such that species less than 100 cm in average length (skipjack tuna, albacore tuna) had relatively low survival and larger species (yellowfin tuna, bigeye tuna, SBT) had relatively high survival. Although these between species differences suggest survival generally increases with size, this is not always the case within a species (Fig. 2*b*), and both negative and positive relationships between length and survival were found in tuna species considered here.

Life status of SBT.—Initial analysis of the box and whisker plots of factors associated with life status of SBT (Fig. 3) indicate that SBT death increased significantly with soak time of sets. The same held true for number of hooks per set, and as one might expect these two factors were highly correlated ($r = 0.59$). There was a weak trend towards increased death at lower water temperatures, but no significant difference between the average length of live and dead SBT.

Since number of hooks was highly correlated with soak time it was excluded from the building of life status models, and only soak time, fish length, and sea-surface temperature (SST) were evaluated. We considered models with polynomial terms up to 4th order. While models with higher order terms appeared to yield ever higher levels of predictive success and ever lower AIC values (which denotes increased parsimony), these models never converged upon an optimum, thus there was no objective means for final model selection. Models with 2nd, 3rd and 4th order polynomials produced qualitatively similar results, and to avoid models with ultra-high order polynomial terms we decided upon a model with 4th order terms: $probability\ (life\ status\ \mathrm{x}) = soak^4 + fish\ length^4 + SST^4$, where x denotes one of the life status categories.

To illustrate the relationship between fish length, SST, and soak time we generated plots of the probability of an individual fish belonging to the different life status categories as a function of soak time while holding SST and fish length constant at three values that reflected the minimum, mean and maximum for the data. The plots in

Fig. 4 generally suggest the probability of a SBT being alive and vigorous (life status category 3 in Fig. 4) decreases markedly with soak time. In most cases the probability was less than 50% after 7 hours (which is less than the 5th percentile in the distribution of soak times observed). Additionally the model predicts the probability of an SBT being dead decreases with water temperature and increases markedly with length at and above sea surface temperatures of 20^{o}C.

DISCUSSION

The data set reported here represents a relatively large proportion of the fleet over a broad region of the ET&BF. However, these results should be considered only as a general snapshot for these years, as it can be expected that species composition and life status may be affected by year-to-year variation in ocean conditions. For instance, the southern edge of the Eastern Australian Current (EAC) was positioned near 35.5^o S in both 2001 and 2002, and SST was near 20 ^{o}C. Conversely, in July 2003 the southern edge of the EAC (and SSTs of 20 ^{o}C) was as far north as 30^o S. This has the potential to shift species composition of the catch in favour of cool water species.

Our multivariate analysis of SBT life status must be considered as preliminary, since our models did not converge upon an optimum. However the generality of increased probability of death with soak time and fish length at higher sea surface temperatures does raise the possibility of formulating management actions to minimize SBT mortality in the longline fishery. Our analysis of other tuna species raises interesting questions of between species differences in mortality in longline catch. The smallest species of tuna (albacore tuna and skipjack tuna) had relatively low proportions of live catch, while larger species (yellowfin tuna, bigeye tuna, SBT) had higher proportions. Given that tunas require continuous swimming to maintain ram-gill ventilation, one could easily speculate that towing a snood line that is fixed to a longline set presents a greater challenge for smaller fish. However, this idea is countered by the strong negative relationships between body size and proportion of live catch for albacore tuna and SBT, suggesting there might be morphological (Magnuson 1973) or physiological (Brill 1994) differences between tuna species affecting their ability to survive. Sharp (1978, as interpreted by Brill 1994 in his Table 1) found sensitivity to low levels of dissolved oxygen to increase with body size (50cm vs. 75cm fork length) for skipjack tuna, yellowfin tuna, and bigeye tuna, but to decrease with body size for albacore tuna. Moreover, the effect of fish length on SBT mortality was temperature dependent (Fig. 4), and thus the observed levels of mortality could be altered by a change in ocean conditions. We suggest further investigations into physiological and environmental factors may prove useful in understanding tuna mortality in longline catch.

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Table 1. Fleet size and observation effort of the eastern tuna and billfish fishery. Fleet effort tallied from vessel logbook records supplied by AFMA and is only for sets that were overlapping (in space and time) with AFMA and CMR observer operations. In 2001 CMR observers were operating from July 11 to August 11 and between latitudes 32.2^{o} S and 36.9^{o} S; in 2002 both AFMA and CMR observers were operating from May 1 to September 26 and between latitudes 29.5^{o} S and 39.8^{o} S.

Year		Fleet	Observed	Coverage
2001	no. boats	34	4	12%
	no. sets	182	20	11%
2002	no. boats	82	36	44%
	no. sets	1,267	212	17%

Table 2. Observed longline catch in the 2002 Eastern Tuna and Billfish Fishery.

Species	Number	Percent	Species	Number	Percent
Tunas			Other fishes		
yellowfin tuna	3,522	41%	black oilfish	999	11%
albacore tuna	1,320	15%	Ray's bream	361	4%
skipjack tuna	498	6%	long nosed lancetfish	265	3%
bigeye tuna	383	4%	dolphinfish	159	2%
southern bluefin tuna	241	3%	oilfish	57	1%
mackerel tuna	12	<1%	sunfish	50	1%
Total	5,976	69%	shortnosed lancetfish	49	1%
Billfishes			rudderfish	24	<1%
broadbill swordfish	201	2%	snake mackerel	15	<1%
striped marlin	101	1%	shortbill spearfish	11	<1%
blue marlin	19	<1%	barracouta	10	<1%
black marlin	11	<1%	pomfret	5	<1%
Total	332	4%	long finned mako	4	<1%
Sharks and rays			dealfish	3	<1%
mako shark	90	1%	bigscale pomfret	2	<1%
blue whaler shark	70	1%	slender barracuda	1	<1%
bronze whaler shark	50	1%	great barracuda	1	<1%
hammerhead shark	48	1%	*Total*	1017	23%
pelagic ray	32	<1%	Sea bird		
tiger shark	13	<1%	flesh-footed shearwater	6	<1%
manta ray	10	<1%	black-browed albatross	5	<1%
whaler shark	9	<1%	great-winged petrel	1	<1%
oceanic white-tipped shark	9	<1%	*Total*	12	<1%
thintail thresher shark	7	<1%	Turtle		
bigeye thresher shark	4	<1%	green turtle	1	<1%
silky shark	4	<1%			
dusky shark	3	<1%			
pelagic thresher shark	3	<1%			
crocodile shark	1	<1%			
porbeagle shark	1	<1%			
Total	354	4%	Total	8,691	

Table 3. Life status of longline catch in the 2002 Eastern Tuna and Billfish Fishery.

Species	Number	Dead	Alive-just	Alive-sluggish	Alive-vigorous
Tunas					
yellowfin tuna	3,522	30%	6%	11%	54%
albacore tuna	1,320	78%	8%	7%	6%
skipjack tuna	498	88%	7%	3%	3%
bigeye tuna	383	33%	14%	18%	36%
southern bluefin tuna	241	29%	5%	2%	65%
mackerel tuna	12	83%	8%	0%	8%
Billfishes					
broadbill swordfish	201	47%	16%	16%	20%
striped marlin	101	46%	1%	14%	40%
blue marlin	19	21%	0%	21%	58%
black marlin	11	45%	9%	18%	27%
Sharks and Rays					
mako shark	90	22%	11%	16%	51%
blue whaler shark	70	4%	3%	11%	81%
bronze whaler shark	50	18%	4%	20%	58%
hammerhead shark	48	21%	8%	17%	54%
pelagic ray	32	0%	3%	9%	88%
tiger shark	13	0%	0%	0%	100%
manta ray	10	0%	0%	0%	100%
whaler shark	9	22%	11%	0%	67%
oceanic white-tipped shark	9	0%	0%	0%	100%
thintail thresher shark	7	29%	14%	0%	57%
bigeye thresher shark	4	25%	0%	50%	25%
silky shark	4	0%	25%	0%	75%
dusky shark	3	67%	0%	0%	33%
pelagic thresher shark	3	33%	0%	0%	67%
crocodile shark	1	0%	0%	0%	100%
porbeagle shark	1	0%	0%	0%	100%
Other fishes					
black oilfish	999	17%	12%	27%	45%
Ray's bream	361	35%	6%	10%	50%
long nosed lancetfish	265	68%	8%	18%	7%
dolphinfish	159	17%	5%	7%	71%
oilfish	57	12%	11%	26%	51%
sunfish	50	0%	2%	18%	80%
shortnosed lancetfish	49	49%	29%	8%	14%
rudderfish	24	0%	58%	29%	13%
snake mackerel	15	67%	13%	7%	13%
shortbill spearfish	11	45%	27%	9%	18%
barracouta	10	80%	0%	20%	0%
pomfret	5	40%	40%	20%	0%
long finned mako	4	50%	25%	0%	25%
dealfish	3	33%	33%	0%	33%
bigscale pomfret	2	100%	0%	0%	0%
slender barracuda	1	100%	0%	0%	0%
great barracuda	1	0%	100%	0%	0%

Table 3 (continued).

Species	Number	Dead	Alive-just	Alive-sluggish	Alive-vigorous
Sea birds					
flesh-footed shearwater	6	100%	0%	0%	0%
black-browed albatross	5	80%	0%	20%	0%
great-winged petrel	1	100%	0%	0%	0%
Turtle					
green turtle	1	0%	0%	0%	100%
Total	8,691	40%	8%	12%	40%

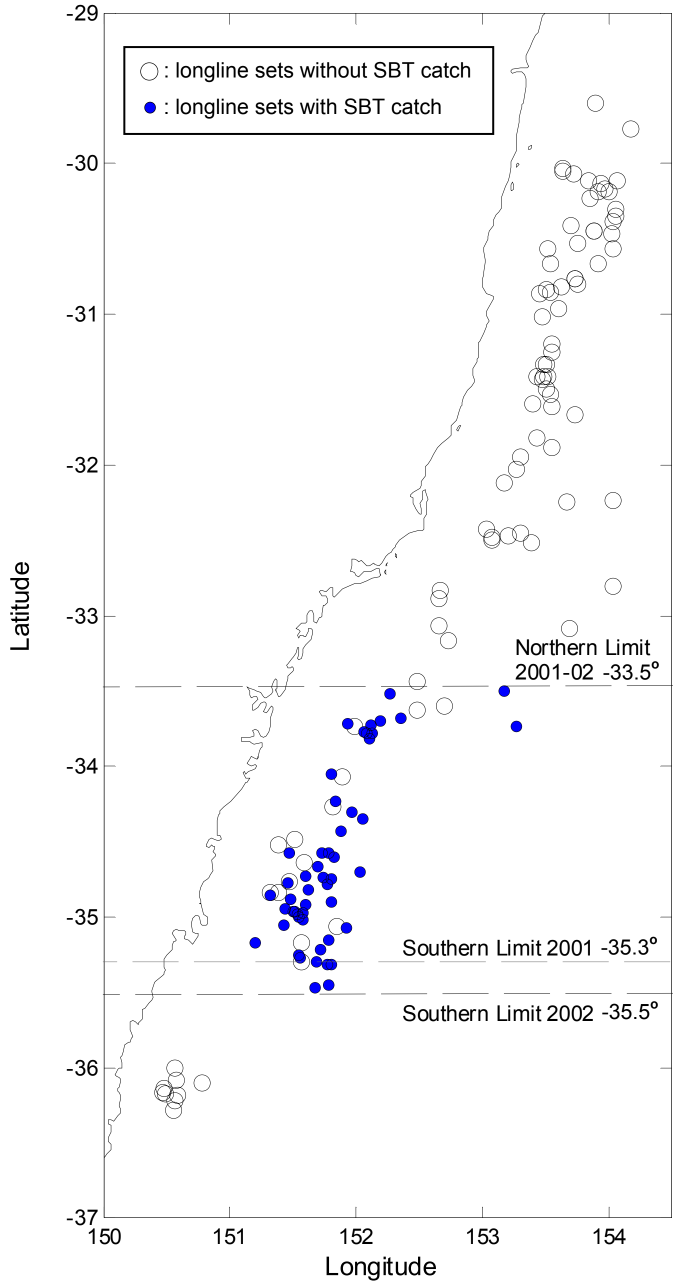

Figure 1. Location of longline sets monitored by AFMA and CMR observers in 2001 and 2002. Southern limit of southern bluefin tuna (SBT) catch in 2002 was further south than in 2001, but northern limit was the same in both years.

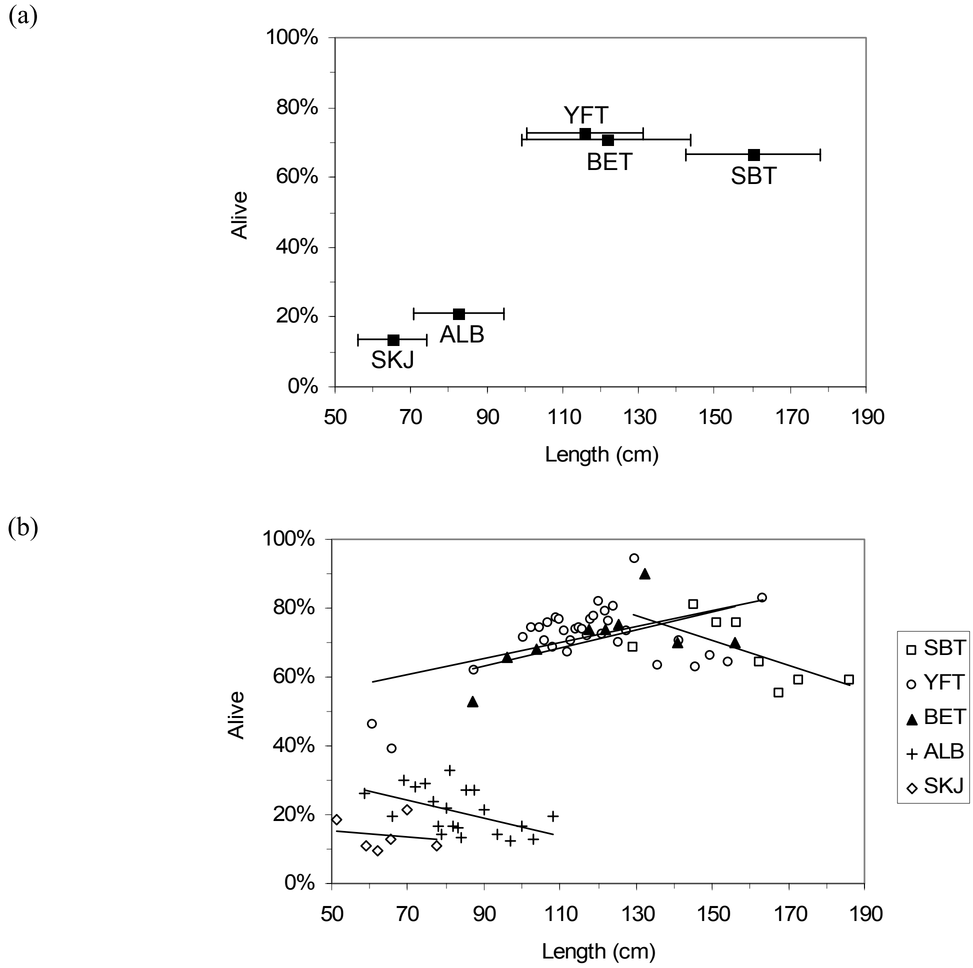

Figure 2. Percent of tuna caught alive by longline fishery versus length in terms of (a) species averages shown with +/- 1 standard deviation, and (b) length class averages within each species, where each length class represents 50–227 fish; ALB, albacore tuna; BET, bigeye tuna; SBT, southern bluefin tuna; SKJ, skipjack tuna; YFT, yellowfin tuna.

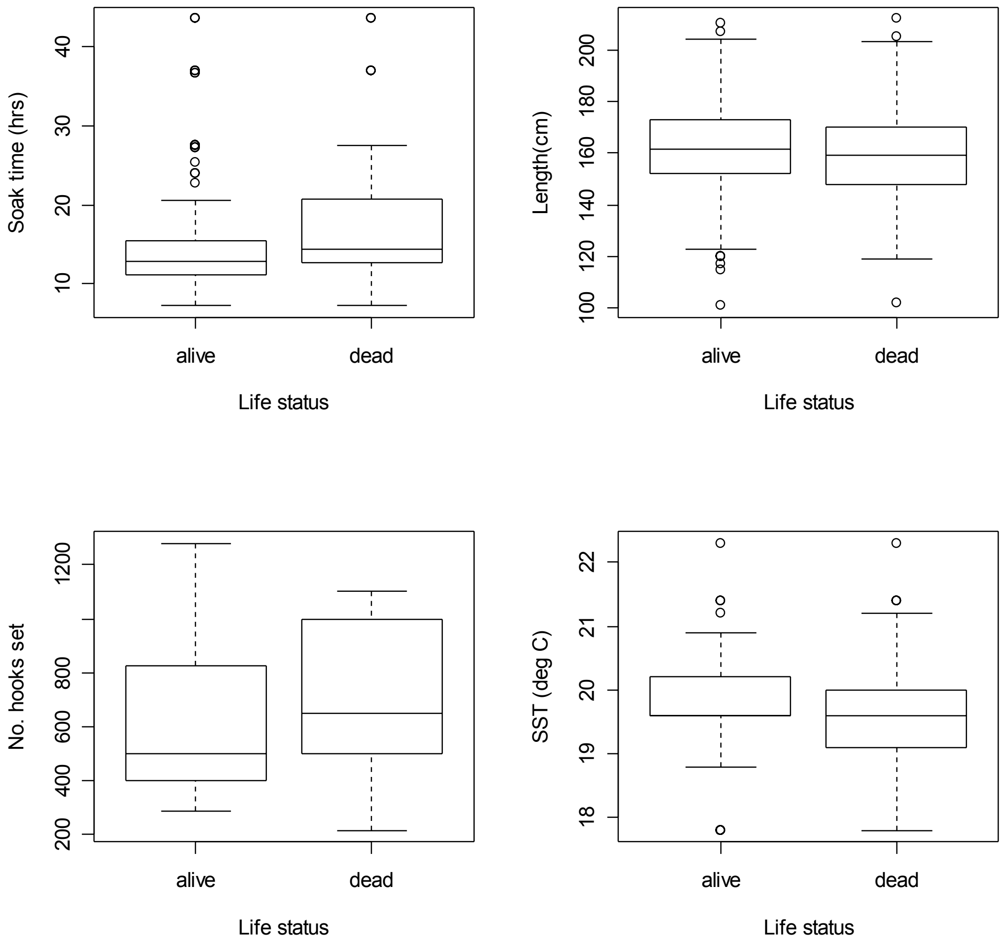

Figure 3. Box and whisker plots of factors associated with life status of southern bluefin tuna caught in longline fishery. Boxes enclose middle 50% of data and mean horizontal line. Upper and lower whiskers extend 1.5 interquartile ranges from edge of box and open circles are data points outside the interquartile range**.**

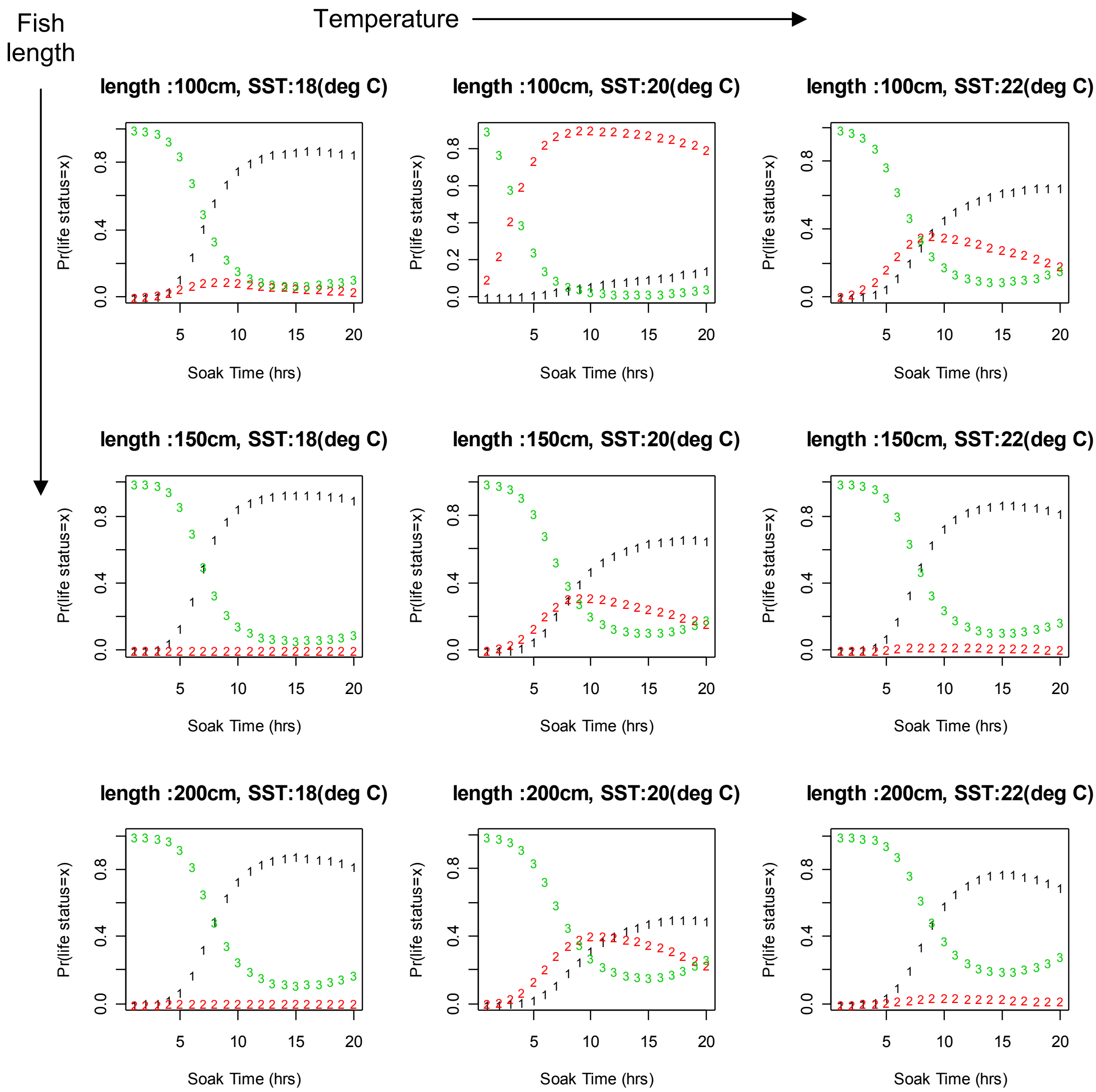

Figure 4. Model predictions for probability of being in a life status category 1 (dead), 2 (intermediate alive), or 3 (alive and vigorous) for southern bluefin tuna caught by longline fishing as a function of soak time of longline set. Values at top of each plot give fish fork length and sea surface temperature (SST) used to generate plots. The probability of being dead (category 1) increases with soak time, and also with fish length at intermediate and highest temperatures, but not at the lowest temperature.