POST-RELEASE MORTALITY OF SCHOOL-SIZE ATLANTIC BLUEFIN TUNA IN THE U.S. RECREATIONAL TROLL FISHERY

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SUMMARY

*Juvenile Atlantic bluefin tuna (*Thunnus thynnus*) have supported an important recreational fishery along the east coast of the United States since the early 1900s. Domestic management measures, including a minimum size limit and increasingly restrictive recreational daily bag limits, have resulted in a fishery that has a high number of regulatory releases. The impact of catch-and-release fishing on the stock is unknown, as there is limited information available regarding the fate of released juvenile bluefin captured under normal recreational conditions. To estimate post-release mortality of "school size" (119 – 169cm CLJFL) Atlantic bluefin tuna caught in the recreational troll fishery using lures or lure/bait combinations rigged with standard J-hooks, we deployed 20 pop-up satellite archival tags programmed to release after 31 days. Nineteen of 20 (95%) tags reported, yielding between 34 and 100% of the archived data. Analysis of temperature, depth, and light data indicated that all 19 fish whose tags reported survived for the tagging period. Three tags released prematurely, after 6, 7, and 26 days, and one tag was consumed by a shark after 12 days. However, all four of these fish displayed behaviour indicative of survival until the tag either released prematurely or was consumed. Although the power of this analysis was limited by the relatively small sample size (n=19), the observed post-release mortality rate of 0% (95% CI: 0%, 10%), suggests that the recreational catch-and-release troll fishery for school size Atlantic bluefin tuna does not represent a significant source of fishing mortality.*

RÉSUMÉ

*Depuis le début du XXe siècle, le thon rouge juvénile de l'Atlantique (*Thunnus thynnus*) alimente une importante pêcherie récréative le long de la côte Est des États-Unis. Du fait des mesures de gestion nationales, y compris une limite de taille minimale et des limites journalières de capture récréative par personne toujours plus restrictives, cette pêcherie connaît un nombre élevé de remises à l'eau réglementaires. L'impact de la pêche de capture et remise à l'eau sur le stock est méconnu, étant donné qu'il existe des informations limitées sur le sort réservé aux thons rouges juvéniles relâchés après avoir été capturés dans les conditions normales de la pêche récréative. Afin d'estimer la mortalité après la remise à l'eau du thon rouge de l'Atlantique susceptible de se déplacer en bancs (119 – 169cm CLJFL) capturé dans la pêcherie de ligneurs récréatifs utilisant des leurres ou une association leurre/appât gréé avec des hameçons standard en forme de J, nous avons déployé 20 marques-archives pop-up reliées à des satellites programmées pour se détacher au bout de 31 jours. Sur les 20 marques, 19 (95%) ont transmis entre 34 et 100% des données archivées. L'analyse des données de température, de profondeur et de lumière a indiqué que les 19 poissons dont les marques ont transmis les données ont tous survécu pendant la période de marquage. Trois marques se sont détachées de façon prématurée, au bout de six, sept et 26 jours et une marque a été avalée par un requin au bout de 12 jours. Toutefois, ces quatre poissons ont tous fait apparaître un comportement de survie jusqu'au détachement prématuré de la marque ou sa consommation. Même si la puissance de cette analyse était limitée par la taille relativement réduite de l'échantillon (n=19), le taux de mortalité observé après la remise à l'eau de 0% (95% CI: 0%, 10%) suggère que la pêcherie de ligneurs récréatifs de capture et remise à l'eau ciblant le thon rouge de l'Atlantique susceptible de se déplacer en bancs ne représente pas une importante source de mortalité par pêche.*

RESUMEN

*Los atunes rojos juveniles (*Thunnus thynnus*) han sido objeto de una importante pesquería de recreo a lo largo de la costa este de Estados Unidos desde comienzos de los 90. Las medidas nacionales de ordenación, lo que incluye un límite de talla mínima y límites diarios por persona*

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para la pesca de recreo cada vez más restrictivos, se han traducido en una pesquería con un elevado número de liberaciones regulatorias. Se desconoce el impacto de la pesca de captura y liberación en el stock, ya que se dispone de información limitada sobre el destino de los atunes rojos juveniles liberados tras ser capturados en condiciones normales de pesca de recreo. Para estimar la mortalidad tras la liberación de los atunes rojos del Atlántico con talla de cardumen (119-169 cm CLJFL) capturados en la pesquería de curricán de recreo utilizando señuelos o combinaciones de señuelo/cebo montados en anzuelos con forma de J, se han colocado 20 marcas archivo vía satélite pop up programadas para desprenderse tras 31 días. Diecinueve de las 20 (95%) marcas transmitieron entre un 34 y un 100% de los datos archivados. Los análisis de los datos de temperatura, profundidad y luz indicaron que los 19 ejemplares cuyas marcas transmitieron información sobrevivieron durante el periodo de marcado. Tres marcas se desprendieron prematuramente, tras 6, 7 y 26 días y una marca fue devorada por un tiburón tras 12 días. Sin embargo, los cuatro ejemplares que portaban estas marcas mostraron una conducta que indicaba su supervivencia hasta que sus marcas se desprendieron prematuramente o fueron devoradas. Aunque la potencia de este análisis se ve limitada por el tamaño relativamente pequeño de las muestras (n = 19), la tasa de mortalidad post liberación observada de un 0% (95% CI: 0%, 10%), sugiere que la pesquería de curricán de recreo de captura y liberación para ejemplares de atún rojo del Atlántico con tamaño de cardumen no representa una fuente importante de mortalidad por pesca.

KEYWORDS

Recreational fisheries, Management measures, Post-release mortality, Tagging, Bluefin

1. Introduction

The U.S. recreational fishery for Atlantic Bluefin Tuna (ABFT) has been operating along the east coast of the United States since the early 1900s (Farrington 1937). Initially, this fishery targeted large ABFT when they congregated on the summer feeding grounds between Rhode Island and Maine. However, as the fishery became more popular smaller ABFT were targeted earlier in the year, starting in North Carolina and moving up the coast to more traditional fishing grounds.. Currently, the U.S. recreational fishery targets juvenile ABFT primarily using trolled lures or lure/bait combinations in waters from North Carolina to Maine. Typically, landings of ABFT in the recreational fishery are dominated by small juvenile ABFT, specifically the "school" size-class (119 – 169 cm curved lower jaw fork length (CLJFL)).

Due to concerns of overfishing of the western stock of ABFT, the International Commission for the Conservation of Atlantic Tunas (ICCAT) has adopted a series of management measures to protect the stock including decreased total allowable catches (TACs), closure of a directed fishery in the Gulf of Mexico, and a minimum size limit. Domestic implementation of ICCAT management measures by the U.S. National Marine Fisheries Service (NMFS) has resulted in greatly reduced bag limits within the recreational fishery. Currently private vessels are allowed to harvest one ABFT between 69 and 185cm CLJFL per day and charter vessels to harvest one ABFT between 69-119cm and one between 119 and 185cm CLJFL per day. The strict bag limits have resulted in large numbers of regulatory releases within the U.S. recreational fishery, but there is little information regarding the fate of these fish.

Electronic tagging methods have been used to investigate the movement and habitat utilization of juvenile ABFT (Brill *et al*. 2002; Galuardi and Lutcavage 2012), and these studies have demonstrated high levels of survival. However, as these studies were not specifically designed to investigate post-release mortality, it is likely that the fish were not handled in a manner typical of the recreational fishery and that only individuals in good condition were selected for tagging. To date, only one study has used pop-up satellite archival tags (PSATs) to investigate the post-release mortality of ABFT, and that focused on giant ABFT (114-445kg) released in an experimental recreational fishery in Canada (Stokesbury *et al.* 2011). To understand the impacts of catch-and-release fishing on juvenile ABFT, we deployed on school-size ABFT caught using standard practices in the U.S. recreational troll fishery.

2. Materials and methods

Tagging operations took place on both charter and recreational fishing vessels offshore of Point Pleasant, NJ and Chatham, MA, USA during the summer of 2012..Cooperating captains and crew were asked to use their standard gear and terminal tackle, and to not modify their normal methods of fighting, handling, or releasing a fish for this study. ABFT were caught on 50-200lb sport-fishing tackle with spreader bars rigged with “J” hooks as the terminal tackle. The first 20 school-size ABFT that were not retained by the vessel were tagged while leaving a minimum of 30min between tagging events to reduce the likelihood of oversampling one school and potentially biasing the results based on the condition of that school.

Once fish were alongside the vessel they were boated by lifting them over the gunwale using the terminal tackle or a lip-gaff (a short gaff inserted into the lower jaw of the animal to assist in boating), or were brought onto the vessel through a tuna door in the transom of the vessel. Once the fish were on the deck of the vessel their eyes were covered with a damp rag, which calmed the fish and reduced the likelihood of further injury to the animal. The hook was removed, the location and severity of any bleeding was noted, the tag anchor was inserted into the dorsal musculature of the animal just posterior and ventral to the anterior insertion of the first dorsal fin, and the fish was released head first over the gunwale or through the tuna door. Gear type, fight time, total time (hooking to release), hooking location, location and severity of bleeding (categorized as no bleeding, light bleeding, or heavy bleeding), overall condition, GPS coordinates of release, date, and length were recorded for each fish.

High-rate X-tags (Microwave Telemetry, Inc. Columbia, MD) which measure 120mm in length, 32mm in width, and weigh 40g in air, were used in this study. The tags were programmed to record pressure (depth), temperature, and light every five minutes for a 31 day deployment, after which the tags released from the fish via a corrosive link and floated to the surface where the data were transmitted to the Advanced Research and Global Observation Satellite (ARGOS) system. The PSATs were also programmed with two emergency release mechanisms; a maximum pressure release, triggered if the tag exceeded 1250m, and a constant pressure release, triggered if the tag remained at a constant depth for four days. These mechanisms ensured that the tags would release from moribund fish and transmit the archived data to the ARGOS system.

Survival of school-size ABFT was determined using the depth and temperature profiles recorded by the PSATs. Depth, temperature, and light profiles of surviving fish exhibit a large amount of variation for the duration of the track, whereas a moribund fish will typically sink to the bottom. It has been shown in previous studies that the majority of mortalities related to the capture and handling events occur within 48hrs of release (Stokesbury *et al.* 2004; Wilson *et al.* 2005). Therefore, five days was used as a cutoff for mortalities related to the capture and handling events following Graves *et al*. (2002).

Net displacement was calculated as the shortest straight-line distance from the point of fish release to the first reliable position of the detached tag (ARGOS location codes 1, 2, or 3). Directions and magnitudes of displacements were generated using ArcGIS 10 (Esri, Redlands, CA).

Bootstrapping simulations were run using software developed by Goodyear (2002) to determine the confidence intervals surrounding the estimate of post-release mortality. This software was also used to determine the minimum number of tags required to reduce the confidence intervals to within 5% of the estimated post-release mortality rate.

3. Results and discussion

Twenty PSATs were deployed on ABFT between June 19 and September 22, 2012 off Point Pleasant, NJ (n=3) and Chatham, MA (n=17, **Table 1**). Fight times ranged from 4 to 11 minutes (7.5 +/-1.9min). Once fish were brought into the vessel the entire tagging process took between 0.5 and 4 minutes (1.7 +/-0.8min). Total time, from hooking to release, ranged from 5.5 to 12 minutes (9.1 +/-0.5min). Fish length was 91 to 119cm CLJFL (108.4 +/-1.9cm) and all fish were hooked externally, meaning the hook was visible and generally lodged in or around the buccal cavity. Ten percent (n=2) of the fish tagged in this study were hooked in the corner of the jaw, 20% (n=4) were hooked in the lower jaw, 55% in the upper jaw (n=11), and 15% in the orbit not puncturing the eye (n=3). Twenty percent (n=4) of tagged fish did not bleed, 70% (n=14) had light bleeding around the hook wound, and 10% (n=2) were experiencing heavy bleeding, one from the orbit and one from the upper jaw, where it was hooked, and from the lower jaw, where it was lip-gaffed.

Nineteen of the 20 PSATs (95%) deployed in this study reported. Of these, four tags released prematurely after 6, 7, 16, and 26 days at large, not inclusive of the four days where the tags were at constant depth (surface) before the release mechanism was triggered (**Table 2**). All 19 reporting tags remained attached for at least six days, exceeding our minimum time threshold of five days to be included in the analysis of post-release mortality. Fifteen tags remained attached for 31 days and the mean time of tag attachment for the 19 reporting tags was 27.3 +/-1.9days. Tags transmitted between 34 and 100% of their archived data (84.8 +/-3.1%, **Table 2**).

All ABFT tagged in June were caught near Point Pleasant, NJ. Two of these fish had net displacements of less than 65km (**Figure 1; Table 2**) over deployment periods of seven and 26 days, while the third individual (BFT-1) had a net movement in a northeasterly direction approximately 266km over 31 days. The remaining 16 fish were caught near Chatham, MA; five in August and 11 in September. Of the fish tagged in August, three had net displacements of less than 100km of the tagging site and moved in a northerly direction while two fish (BFT-4 and BFT-8) had net displacements of approximately 207km and 118km, respectively, in a southwesterly direction. Fish tagged in September typically had longer displacements (172.4 +/- 30.8km). Nine fish had net displacements in a southerly direction while two (BFT-10 and BFT-11) had net displacements almost due east.

Based on visual inspection of the depth, temperature, and light profiles we inferred that all 19 individuals with reporting tags survived. The tag of BFT-16 (and possibly the individual) appears to have been consumed 12 days after release. This is evident from a visual inspection of the depth, temperature, and light profiles from the tag data (**Figure 2**). The depth profile reveals consistent vertical behavior for the duration of the tag deployment, while the temperature profile indicates an abrupt increase in temperature from ambient on October 2nd. From October 2nd to October 6th the temperature remained elevated and did not vary with depth. Concurrent with the increase in temperature was a decrease in light and a loss of the day/night signal. These temperature and light data are consistent with the tag having been consumed by an endothermic organism. As this apparent predation event occurred 12 days after release of the fish it was not considered a fishing-related mortality for the purposes these analyses. Based on these data, survival of all 19 fish results in an estimated mortality rate of 0% for school-size ABFT released in the recreational troll fishery. Using an observed mortality rate of 0%, the results of 10,000 simulated experiments indicate the 95% confidence intervals for an experiment deploying 19 ranged from 0 to 10% (**Figure 3**).

There is a large recreational fishery for ABFT in the United States which is typically dominated by the school size-class and most fish are caught using trolling methods. Due to the large number of regulatory releases in the U.S. recreational fishery it is important to understand the fate of those released fish. While there have been two studies investigating the post-release mortality of ABFT (Skomal *et al.* 2002; Stokesbury *et al.* 2011) neither investigated the U.S. recreational troll fishery. Skomal *et al.* (2002) investigated the chunk bait fishery for juvenile ABFT (63-131cm curved fork length) and compared circle and “J” hooks by inferring mortality based on hooking location. They found a reduced mortality for ABFT caught on circle hooks (4%) versus those caught on “J” hooks (28%). Stokesbury *et al.* (2011) deployed 59 PSATs to investigate post-release mortality of giant ABFT (114-455kg) caught in an experimental recreational fishery in Canada. In the study fish were captured using custom-made, barbless circle hooks and only experienced captains and anglers were used. One mortality was observed prior to tagging and two additional mortalities were inferred after release based on the PSAT data. Four tags did not report and were excluded from the calculation of post-release mortality, yielding 3 mortalities out of 55 tags or a post-release mortality rate of 5.6%.

Data from the current study indicated a post-release mortality rate of 0% (CI: 0%, 10%). This rate is lower than that observed by either previous study and is likely a function of the fishing method used. In the chunk bait fishery the fish are more likely to swallow the bait and therefore are more likely to sustain internal damage from the hook. In high speed troll fisheries the fish typically attack the bait much more aggressively, resulting in the hook lodging in or around the mouth (Graves and Horodysky 2010; this study).

The current study was limited by a small sample size (19 reporting tags) and it is highly likely that the true mortality rate is greater than 0%. We estimated the number of tags necessary to reduce the 95% confidence intervals to within 5% of our estimate of post-release mortality to be 60 tags, using software developed by Goodyear (2002). However, if a single mortality had been inferred in this study it would change the estimated post-release mortality rate to 5.3% and greatly expand the 95% confidence interval to between 0 and 21%. Using these criteria a minimum of 200 tags would need to be deployed in order to reduce the confidence intervals to within 5% of the true mortality rate. With the current cost of PSATs near $4,000 it is not economically feasible to explore the post-release mortality rate of school-size ABFT in the recreational troll fishery to the extent necessary to obtain a high-precision estimate. However, based on the results of this study it is apparent that the post-release mortality rate of school-size ABFT in the recreational troll fishery is low. Between 2005 and 2010, the estimated number of released school-size ABFT has ranged from 2,100 to just over 21,000 individuals (**Table 3**). Assuming a post-release mortality rate of 5%, the estimated number of post-release mortalities of school-size ABFT over those years would have ranged from 105 to 1073 individuals. When compared to the overall U.S. recreational and commercial ABFT landings in these years, 6,150 to 15,204 ABFT, it is evident that the post-release mortality of school-size ABFT in the U.S. recreational troll fishery is likely not a large contributor to the overall fishing mortality.

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Table 1. Catch information for 20 school-size ABFT caught by trolling in the U.S. recreational fishery and tagged with PSATs in the summer of 2012. Deployment location NJ is off of Point Pleasant, NJ and MA is off of Chatham, MA.

Fish	***Deployed (2012)***	***Deployment Location***	***Length (cm)***	***Hooking Location***	***Bleeding***	***Location of Bleeding***	***Fight Time (min)***	***Tagging Time (min)***	***Total Time (min)***
1	19-Jun	NJ	109	corner of jaw	None	NA	7	3	10
2	19-Jun	NJ	107	orbit	Heavy	orbit	7	4	11
3	19-Jun	NJ	102	upper jaw	Light	under orbit	10	2	12
4	2-Aug	MA	109	upper jaw	Light	upper jaw	6	2	8
5	2-Aug	MA	107	corner of jaw	None	NA	6	1	7
6	2-Aug	MA	107	lower jaw	Light	lower jaw	9.5	1	10.5
7	4-Aug	MA	107	upper jaw	Light	upper jaw	6	1	7
8	29-Aug	MA	117	orbit	Light	orbit	7	2	9
9	12-Sep	MA	114	lower jaw	Light	lower jaw	11	1	12
10	12-Sep	MA	114	upper jaw	Light	upper jaw	4	2	6
11	14-Sep	MA	109	upper jaw	Light	upper jaw	9	2	11
12	14-Sep	MA	117	upper jaw	Heavy	upper jaw and lip-gaff wound under jaw	7	2	9
13	15-Sep	MA	117	upper jaw	Light	upper jaw	5	1	6
14	15-Sep	MA	114	upper jaw	None	NA	5	0.5	5.5
15	15-Sep	MA	91	upper jaw	Light	upper jaw	6	1	7
16	21-Sep	MA	91	lower jaw	Light	lower jaw	7.5	2	9.5
17	21-Sep	MA	119	upper jaw	Light	upper jaw	10	1	11
18	22-Sep	MA	99	upper jaw	None	NA	8	1	9
19	22-Sep	MA	99	lower jaw	Light	lower jaw	9.5	1.5	11
20	22-Sep	MA	119	orbit	Light	orbit	9	2	11

Table 2. Tagging and reporting dates of 20 PSATs deployed on school-size ABFT caught by trolling in the U.S. recreational fishery during the summer of 2012. Asterisks indicate tags that released prematurely.

Fish	*Deployed*	*Reported*	*Days Deployed*	*% Data*	*Straight Line Distance (km)*
1	6/19/2012	7/19/2012	31	79	266.1
2*	6/19/2012	6/29/2012	7	34	36.4
3*	6/19/2012	7/15/2012	26	86	62.1
4	8/2/2012	9/2/2012	31	89	207.3
5	8/2/2012	9/2/2012	31	85	44.4
6*	8/2/2012	8/8/2012	6	100	59.4
7	8/4/2012	9/4/2012	31	80	97.9
8	8/29/2012	9/28/2012	31	89	118
9	9/12/2012	10/12/2012	31	86	134.6
10	9/12/2012	10/12/2012	31	86	109.6
11	9/14/2012	10/14/2012	31	88	48.6
12	9/14/2012	10/14/2012	31	87	245.1
13	9/15/2012	10/15/2012	31	87	402.5
14	9/15/2012	10/15/2012	31	88	189.9
15	9/15/2012	10/15/2012	31	91	121.3
16*	9/21/2012	10/6/2012	16	98	18
17	9/21/2012	10/21/2012	31	89	169.8
18	9/22/2012	10/22/2012	31	90	116.4
19	9/22/2012	10/22/2012	31	80	185.8
20	9/22/2012				Did Not Report

Table 3. Landings and releases by individuals in the U.S. Atlantic Bluefin Tuna fishery. Releases are for school-size fish (119 - 169cm CLJFL) within the recreational fishery and the estimated release mortality assumes a 5% post-release mortality of school-size Atlantic Bluefin tuna within the U.S. recreational fishery.

Year	*Recreational Landings*	*Commercial Landings*	*Total Landings (Recreational + Commercial)*	*School-Size Releases*	*Release Mortality*
2005	10071	2459	12530	21469	1073
2006	4917	1233	6150	8222	411
2007	14187	1017	15204	6902	345
2008	10741	1531	12272	4923	246
2009	10158	2487	12645	2100	105
2010	4085	3635	7720	4378	219

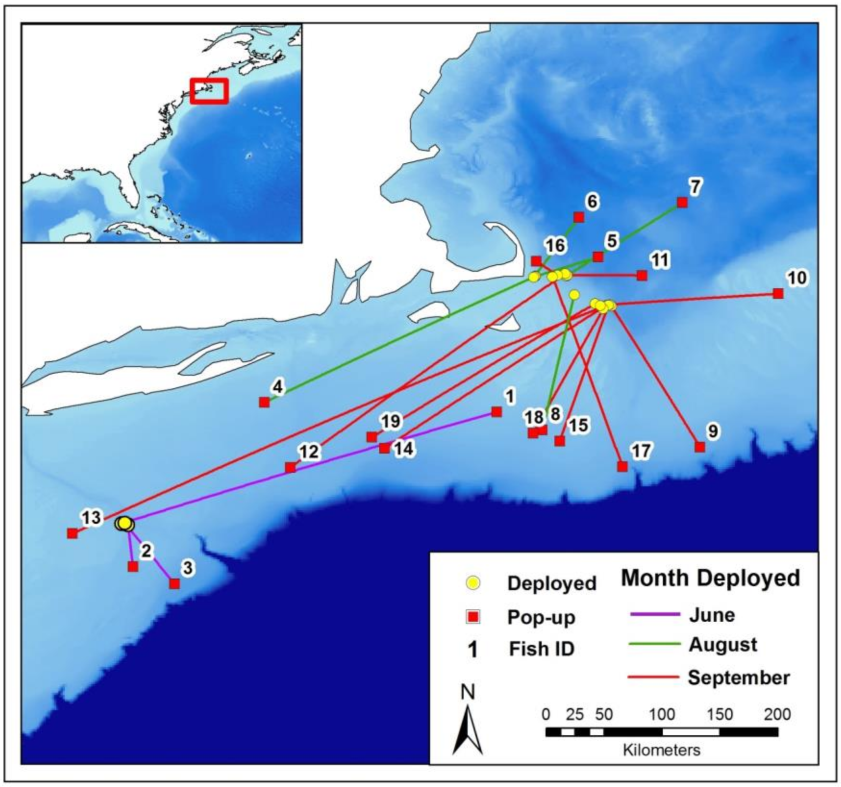

Figure 1. Tagging and pop-up locations of PSATs deployed on school-size Atlantic bluefin tuna during the summer of 2012. Tagging and pop-up locations are denoted by the yellow circles and red squares, respectively. The distance traveled by each fish is indicated by the purple lines for fish released in June, green lines for August, and red lines for September).

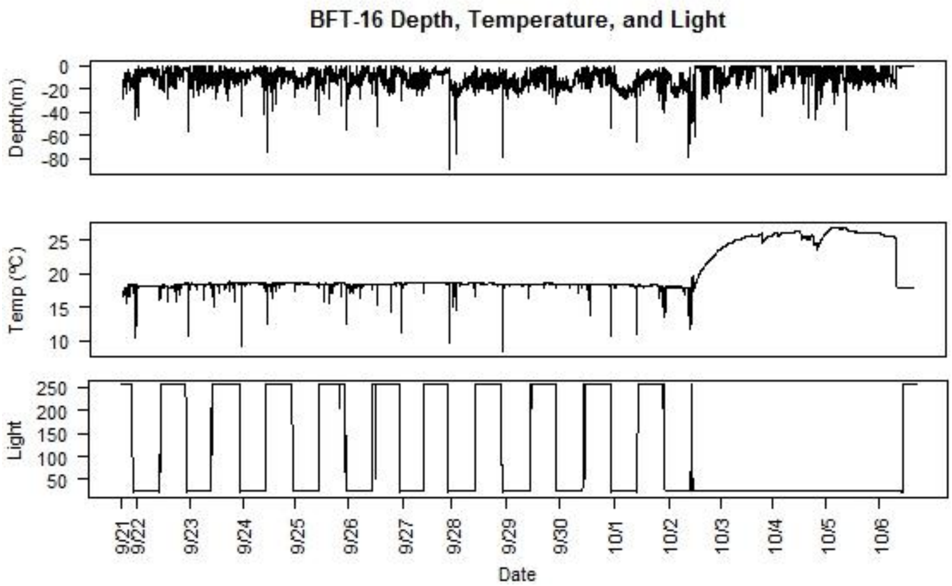

Figure 2. Depth, temperature, and light profiles for BFT-16 over the 16 day pop-up satellite archival tag deployment period. The data are consistent with the tag (and possibly the fish) being consumed. Note an abrupt increase in temperature on October 2nd (day 12), and a lack of variation in temperature with depth after that date. On October 2nd there was a loss of the day/night cycle. These data are consistent with predation by an endothermic predator, most likely a shark.

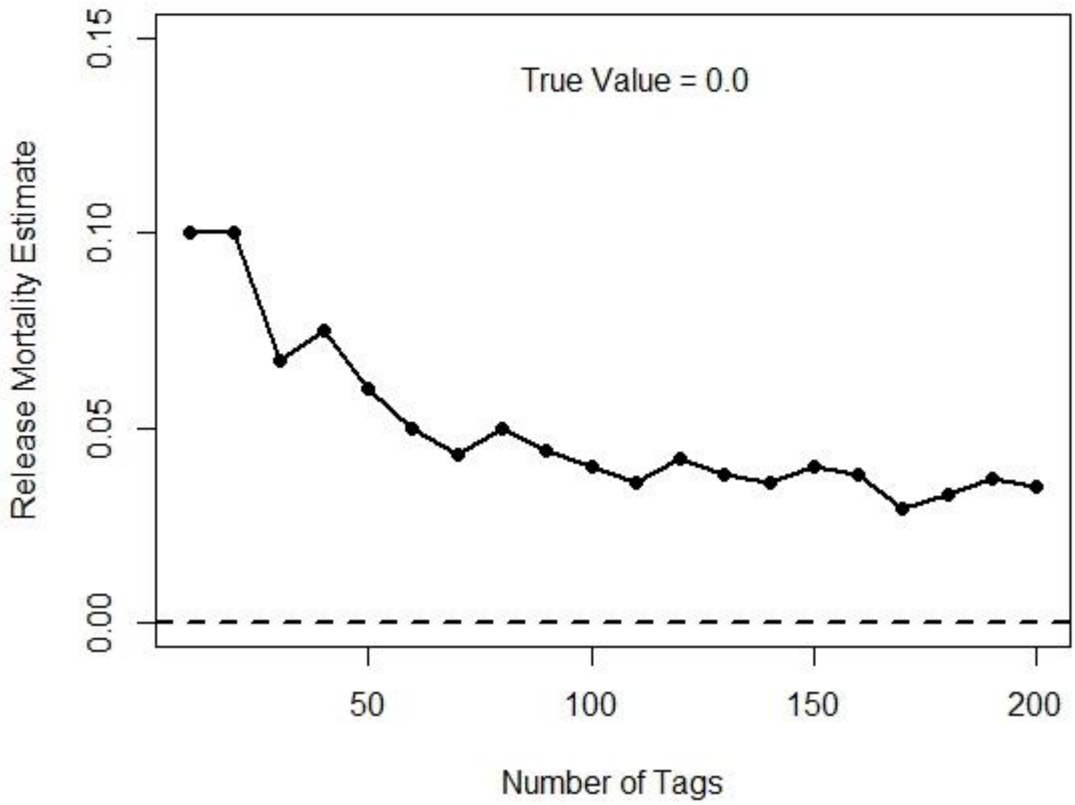

Figure 3. Confidence limits around the estimated post-release mortality rate of 0% with varying numbers of tags deployed; confidence intervals were estimated following Goodyear (2002).