SCRS/200x/186

RESULTS OF A PILOT ARCHIVAL TAGGING PROGRAMME INCLUDING A PRELIMINARY ANALYSIS OF FACTORS, AT THE POINT OF RELEASE, AFFECTING TAG RECOVERY FOR ALBACORE TUNA (*Thunnus alalunga*) IN THE NORTH EAST ATLANTIC

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SUMMARY

This paper describes a pilot archival tagging study on albacore tuna, carried out in the Bay of Biscay from 2005 to 2008. Involving several European Institutes, the study aimed to obtain an estimate of recovery rates for fish tagged with 'dummy' archival tags, in order to assess the feasibility of conducting an archival tagging study for albacore tuna in the North East Atlantic. A total of 353 fish were tagged and released and 8 fish (2.27%) were recaptured. A database of conventional tagged albacore tuna provided by ICCAT permitted a multivariate analysis of factors affecting tag recovery such as fishing gear, month, effort level and fish size, at the time of release, to be carried out using a binary logistic regression. The results of this analysis suggest that fish which are caught by trolling, between 65 and 74 cm FL, during periods of relatively high fishing effort, at the point of release, have the highest probability of recapture in the North East Atlantic..

KEYWORDS

Albacore. Tagging. Dummy. Archival. Bay of Biscay, tag recovery, multivariate analysis

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1. Introduction

A number of conventional tagging studies for albacore have been conducted in the North Atlantic and Mediterranean since the 1960s. These studies have been well described and summarised (Arrizabalaga *et al*., 2002). Information was obtained on horizontal movements of albacore tuna, from which it was possible to draw a number of conclusions; the hypotheses on two separate stocks existing in the North and South Atlantic was supported, long distance transoceanic movements were confirmed, and limited mixing between the North Atlantic and Mediterranean was found to occur.

Archival tagging studies which provide detailed information on migratory paths, temperature and depth preferences, can lead to improved information on fish behaviour and physiological adaptations to oceanographic features. External pop-up archival tags (PAT tags), which transmit data via satellite systems and are therefore fishery independent, are used extensively in experiments on large pelagic species such as Atlantic bluefin tuna *Thunnus thynnus* (Block *et al*. 2001). New versions of these tags may be small enough to deploy on albacore tuna but the duration of attachment and general performance of these tags has yet to be tested with this species. Smaller, internally implantable, archival tags can collect data for periods of up to several years and although fishery dependent, represent the best option for obtaining long term archived data sets at present.

Given a relatively high unit cost of archival tags, an estimated expected tag recovery rate should be determined, in order to assess the number of tags and associated financial investment required, to ensure sufficient recoveries from an archival tagging experiment. A number of uncertainties exist in the North East Atlantic in this regard.

Although archival tags have been used extensively for other species of tuna, their use with albacore is relatively new. An albacore archival tagging programme commenced on the west coast of the US, as part of the Tagging of Pacific Pelagics Programme (TOPP) in 2001, and 16 archival tags have been recovered by US fishermen from 116 deployments (14% recovery rate) since 2003 (Childers, 2005). Also, Uosaki (2003) reported preliminary results of one recapture from 40 albacore tuna, tagged and released with archival tags near Japan in the Pacific. However, an archival tagging programme for albacore tuna has yet to be carried in the North Atlantic. In addition the albacore fishery, which is primarily conducted in the Bay of Biscay, is relatively complex. It is primarily exploited by 3 different nations with 3-4 different languages, employing a wide variety of fishing methods on a highly seasonal basis, which may complicate the process of recovering tags from recaptured fish. It was hoped, however, that the multinational collaboration of institutes from Ireland, the Basque Country and Spain on this project, would assist in addressing this issue.

This study aimed to obtain an estimate of recapture rates for fish tagged using ‘dummy’ archival tags, in order to assess the feasibility of conducting an authentic archival tagging programme for albacore tuna in the North East Atlantic. In addition a database of conventional tagged albacore tuna was made available by ICCAT which permitted an analysis of factors affecting the recovery of tagged albacore, at the point of release, which will assist in planning future tagging programmes in the North East Atlantic.

2. Materials and Methods

2.1 Fishing Operations

Tagging was carried out in July 2005 and 2006, onboard chartered Irish fishing vessels. Trolling gear was used for the experiment as Irish vessels have formerly successfully employed this method. Spanish and Basque trolling vessels have a long history and considerable expertise in this fishery and fishing was conducted along side these vessels where possible. Similar fishing methods were employed in 2005 and 2006, but different vessels were chartered. In 2005, a 20m vessel constructed of wood, the MFV Mellifont from Duncannon, Co. Wexford was employed. In 2006 the MFV Ocean Dawn from Fenit, Co. Kerry was chartered. This vessel was approximately 15m long with a steel Hull. Both vessels were fitted out with steel outriggers and American hydraulic line winches utilising a total of 12 to 14 trolling lines, with various sizes of double barbless hooks. Trolling was carried out at a speed of approximately 6 knots, but vessels slowed when a fish was hooked, to be taken aboard for tagging. Rubber bungees were present on all lines to absorb the tension of the fish bite.

2.2 Fish Handling

Fish were landed in a scoop landing net with nylon, knotless netting onto a carpet, on the deck at the stern of the vessel. Only fish in good condition, hooked through the lower lip were selected for tagging. Two 1m stainless steel V-shaped tagging cradles were specially constructed for this study, and were lashed to rails at the side of the vessel for the duration of the experiment. The cradles were also fitted with built in measuring rulers and plastic containers at the top end for storing tags and related equipment in betadine, antiseptic solution during surgery. A hose containing a clean flow of pumped seawater was inserted through a gap at the top of the cradle, in order to irrigate the gills during tagging. Fish were blindfolded with a light sheet of black PVC during tagging.

2.3 Tagging

Dummy tags were based on Lotek LTD2410, archival tags which were the smallest full featured geolocator and temperature-depth recorders available. The dummies were constructed in plastic moulds from epoxy resin, with lead shot and protruding fishing gut, to emulate the light sensor stalk. They had the exact same dimensions as the genuine archival tag; 37mm length x 11mm diameter and 6.2g in weight. A label with a contact number for recaptures was also embedded in the tags.

An incision was made with a scalpel, posterior to the pelvic fins, and a finger was used to penetrate the peritoneum. The tag was inserted in the peritoneal cavity and a single surgeon's flat knot was used to seal the wound. Depending on the size of the fish, 1 – 3ml of 20% Oxytetracycline (OTC) solution was injected into the dorsal musculature of the fish, to facilitate age validation studies, where whole fish were recovered (McFarlane and Beamish, 1987). In Year 1, a small amount of Betamox (1 – 2ml) was injected into the wound from a syringe without a needle, but this was not carried out in Year 2, as it was surmised that the dosage of OTC should provide a sufficient amount of antibiotic.

A conventional floy tag with contact details was inserted at the base of the second dorsal fin. Following completion of these procedures, the fish was checked to ensure it was still in good condition, and released over the side of the vessel. Tag numbers, geographic position, date, operating time, fish condition and time of release were recorded for all tagged and released fish.

2.4 Reward and Publicity

A reward of €200 was available to fishermen who recaptured and submitted a fish with a dummy archival tag to an appropriate institute. This sum was consistent with the reward provided by the Basque Institute AZTI, in a juvenile bluefin tuna tagging programme in the Bay of Biscay, which deployed both dummy and authentic archival tags. The reward and the study were advertised, through the distribution of posters to relevant research institutions, fishermen's organizations and fishermen, and adverts placed in trade publications in Spain, France and Ireland.

2.5 Analysis of Factors affecting recovery

A conventional tagging dataset provided by ICCAT in July 2008 consisted of tagging release and recapture records for albacore tuna in the North Atlantic and Mediterranean from 1960 up to 2007. The dataset was analysed and edited primarily with optimal conditions/methods for future tagging programmes in mind. Factors associated with the initial release of recaptured fish eg. size of fish or fishing method used to catch and release fish, were therefore analysed to examine if optimal tagging conditions could be predicted using a statistical model. If suitable 'conditions' could be predicted, then the likelihood of recapturing fish in future tagging programmes would increase, if these conditions were followed. A Binary Logistic regression using a binary response variable with 2 possible outcomes, recaptured or not recaptured, was used to investigate the influence of various factors, at the point of release, on the probability of recapture, with statistical package Minitab Version 15. The data set was edited with a view to providing a meaning multivariate analysis and the following categorical factors were included in the model:

Length class (5 levels: <55, 55-64, 65-74, 75-84, >84 cm fork length)
Effort level (2 levels: low <6300 and high >12000)
Stock size
Fishing gear (2 levels: Bait boat and Troll)
Month of release (4 levels: 7, 8, 9, 10)

Most tagging was carried out by Spain relatively close to the Spanish coast so in this context the data set was not ideal for analysing the effect of location or zone of releases on recaptures and zone was therefore not included. Fish size is a factor which is simple to control at the point of tagging and the size categories outlined above were used in the model.

Fishing effort was considered to be a variable which could have a major effect on the likelihood of fish being recaptured. Standardised effort data for the Spanish Bait boat and Troll fleets were available for the years 1981 – 2005 (Ortiz de Zarate and Ortiz de Urbina, 2007a, 2007b). A total of 78% of fish recaptured from the final dataset were finally caught by Bait boat or Troll. In addition 68% of all albacore landed in the North Atlantic were caught using these methods in 2006 (ANON, 2008b) so it was assumed for the purposes of this study that these effort data could be used as an index to represent all fishing activities. Standardized effort data provided in days in calendar quarters, were added to provide yearly estimates for each fishing method. Yearly estimates of standardized fishing effort were added together, and aggregated for periods of 3 years from release. In addition to providing a more balanced estimate of fishing effort, to which tagged fish were subjected, this approach assisted in dealing with gaps in the tagging data set when no tagging occurred, but fish released in previous years were still likely to be recaptured. The period of 3 years was based on the period of liberty of tagged fish, with 95% of recaptures in the final dataset, occurring in the first 3 years from release. The cumulated effort data fell into 2 categories with 4 years with less than 6300 effort days between the years 1983 -1986 and a further 4 years with more than 12000 days between the years 1988 - 1991

Population estimates were included in the model as, in theory, the higher the population the lower the chance of fish recapture. Stock size at age estimates for the VPA model used in the albacore stock assessment (Anon, 2008a), were added together to provide total annual population estimates. These data were then aggregated for periods of 3 years from release similar to the procedure carried out for effort data as described above. These data were not, however, categorised but left as individual yearly data points. Two fishing methods used to catch and release fish remained in the data set following editing of the data set (see results) and the 4 months, July to October, when tagging occurred were also included in the analysis.

Most tagging to date has been carried out in the Bay of Biscay and this is the likely location of future tagging programmes. Therefore the data were restricted to releases carried out in the North East Atlantic, leaving 3 fleets which had carried out tagging programmes, EC Spain, France and Ireland. A very high proportion of tag recaptures occurred for fish that were released by French trolling vessels which may have been caused by some retrospective updating of the database in response to data provided on recaptured fish. These data were removed from the dataset. The data from EC Ireland were also removed as these were exclusively fish that were tagged by the dummy archival tagging method, in a different geographic area with higher rewards available than conventional tagged fish.

Following the removal of duplicate files the remaining data on tag releases by year and gear type are outlined in Table 2. In recent years tagging effort has switched from commercial bait boat and trolling vessels to Sports vessels with a particularly big effort in 2006 with 2124 (86%) of all Sport released fish in that year. No recapture data were available for these fish and it was assumed that the database had not yet been updated with recapture information. Fish caught by Sports fishing were therefore excluded from the data set. A total of 721 Rod & Reel records representing 4.2% of all tagged fish from this data set had a recapture rate of 0.97% which was considerably lower than the recapture rates observed from Bait boat (2.92%) and Troll (4.64%). In addition tagging by Rod and Reel was carried out from 2001 to 2004 when no tagging was carried out by the principal 2 methods. Taking these factors into account, it was decided to remove Rod and Reel records from the dataset so as not to negatively affect the analysis of the principal gear types.

Tagging records prior to 1981 when no effort data available were excluded from the dataset. Small release events consisting of less than 3 fish releases in a year were also excluded, leaving a final dataset of Bait boat and Troll released fish from the North East Atlantic between the years 1983 to 1991, with a total of 13187 release records and 422 associated recaptures.

3. Results

3.1 Dummy archival tagging

In 2005, fishing and tagging operations were conducted within a relatively small geographical area, in North Bay of Biscay, from 15th to 22nd July and a total of 199 fish were tagged and released with dummy tags. In 2006, fishing was carried out slightly further to the southwest, over a slightly bigger geographical range, from 20th July to 2nd August. A total of 154 fish were tagged and released in 2006, bringing the total number of fish tagged for both years to 353.

The system of tagging worked best with two people managing the operation, one holding the fish steady and keeping the hose in the mouth, and the other conducting surgery. Almost all fish were calm and still once placed upside down in the tagging cradle, blindfolded and the gills well irrigated. Some fish, which continued to thrash about during the operation, were rejected and on several occasions tags were removed, as it was not possible to stitch the wound to a satisfactory level. The v-shaped cradle worked well but the design could be improved if the angle of the side of the table was increased from 30^o to 45^o or more, to assist in holding the fish steady.

Trolling generally catches juvenile albacore tuna which are prevalent close to the sea surface, and this was found to be the case during the tagging experiment. The average size of tagged fish was 62 cm FL, corresponding primarily to age 1 and 2 fish. Tagging operations from time of fish landing to fish release, took an average of 3 minutes and 6 seconds and fish were generally very lively at the point of release.

Information on recoveries is summarised in Table 1. A total of 8 fish were recaptured from 353 releases equating to a 2.27% recovery rate. A total of 7 dummy archival tags were recovered. On one occasion the conventional floy tag was returned by the fisherman, but not the dummy archival tag. The fish was sent to a canning factory and it was not clear if the tag was undetected or had been shed by the fish while at liberty. The initial sizes of recaptured fish when released, ranged from 58 to 76cm with a mean of 66.25cm FL. Seven out of eight of these, were greater than the mean size of released fish, 62cm FL. A two sample Z test for differences in the mean sizes showed that the difference in mean size of all released fish and the sub sample of released fish that were subsequently recaptured was significant ($P = 0.01$., $\alpha=0.95$).

Four of the fish were recaptured by live bait boats, 3 by pelagic trawlers and 1 by a trolling vessel. Recapture data such as location, date and size were received for 6 of the 8 fish. For the 2 fish where no report was received from the fisherman, it was possible to estimate the dates but not the location nor the size of recaptures.

The number of days at liberty ranged from 60 to 810, with a mean of 531. One fish was caught in the same fishing season/calendar year, 3 were caught in the following year and 4 were caught approximately two years after release. One fish was caught by a trolling vessel early in the season in May near the Canary Islands, 3 fish were recaptured in the southern Bay of Biscay in July and 2 fish were caught towards the northern Bay of Biscay and south west of Ireland in September and October (Figure 1.) The straight line distances from points of release to recapture, ranged from 197 to 2911km, with an average distance of 923km. The mean growth rate of 6 recaptured fish for which size data were available, was 7.48mm month^{-1} and ranged from 5.81 to 9.96mm month^{-1}, with a standard deviation of 1.45mm month^{-1}.

3.2 Factors affecting tag recovery

The results of the binary logistic regression on the final data set are outlined in Table 3. The model outputs suggested that length class, effort level and fishing gear at the point of release had a significant influence on the probability of recapture ($p<0.05$). Population size and month at the point of release did not affect the probability of recapture and these factors were removed from the model. Fishing gear used to catch fish at the point of release was the factor which had the greatest influence on probability of recapture and trolling was the optimal method (odds ratio -6.8, $P<0.001$).

The length at release also affected probability of recapture. The highest recovery rates were achieved for fish that fell in the length class 65-74 on release (5.3% recovery). The model showed that these fish had a higher probability of recapture than fish <55cm (odds ratio -5.5, $P<0.001$), from 55 – 64cm (odds ratio, -3.4, P=0.001) and fish from 75 – 84cm (odds ratio -2.5, P=0.13). Fish >85cm were less likely to be recaptured (odds ratio -1.2), but this difference was not significant. Examination of the basic data showed differences in recovery rates by length class at the point of release for each fishing method. The inclusion, therefore, of an interaction between length class and fishing gear slightly improved the model fit.

Effort during the years following release was predicted to have a relatively strong effect on recaptures with a higher probability of recapture during years of high fishing effort (odds ratio – 2.6, P=0.009).

In terms of model diagnostics, the model coefficients were significantly different from zero (G = 62.7; $p<0.001$). The results of the goodness-of-fit tests (Pearson, deviance, and Hosmer-Lemeshow $p>0.05$) shows insufficient evidence that the model does not fit the data adequately. However McFadden's Rho-Squared is low (0.017), indicating that the model describes only a small amount of the variability in the data; values of 0.2 – 0.4 are generally considered satisfactory, (Hensher and Johnson 1981).

4. Conclusions

Recaptured dummy archival tagged fish did not move in a straight line and may have made a number of seasonal migrations. However it is interesting to note that the time and location of dummy recaptures corresponded closely to the perceived North East Atlantic seasonal migration route; travelling north from the coasts of Africa and Portugal into the Bay of Biscay and northwest towards the coast of Ireland at the end of the season, before returning south. One fish was recaptured off the Canaries having traveled 2911km which is a relatively long distance when compared with conventional tagging studies, where just 4 out 643 tagged albacore were recaptured at a distance greater than 2000 miles (3220 km) from point of release (Arrizabalaga *et al*., 2002).

The mean growth rate of recaptured dummy tag fish (7.48mm $month^{-1}$) was smaller than the mean growth rate of conventional tagged fish from the final data set used in this study (10.29mm $month^{-1}$). However the mean size of recaptured fish when released was smaller for the conventional tagging study (59.21cm FL) than the dummy study (66.25cm FL). The mean growth rate of released fish of 66cm FL from the conventional study was 8.7 $month^{-1}$ which is closer to the mean growth rate of recaptured dummy tagged fish. Although small sample size prevents more detailed analysis of growth from the dummy tagging study, it appears from the figures above that no major negative effect on growth is caused by internally implanting tags of the size used in this study in albacore tuna.

Although an important effect in the multivariate analysis, fishing effort is beyond the control of biologists planning tagging programmes and is not something that can be adjusted to favour tag recaptures. However the study has shown that fish are more likely to be recaptured during periods of relatively high fishing effort and this has been the case in recent years with combined effort of Bait boat and Troll fleets reaching new levels in excess of 7000 days a year in 2004 and 2005.

Month was not found to be significant in the present study but this result should be treated with caution given that tagging effort is unlikely to follow normal fishing patterns, but rather follow optimal conditions which suit the presence of biologists onboard vessels. It may be prudent, therefore, in future tagging surveys to carry out tagging relatively early in the tuna season, close to the coast of Spain, which will permit fish to be targeted throughout the remaining season as fishing vessels follow them on their seasonal migration.

The higher probability of recapture of Troll caught over Bait boat caught fish was a surprising result as it generally takes longer to bring Troll caught fish aboard and they are hauled against a strong flow of water as the vessel travels at a speed of 6 -7 kts while fishing. Once hooked, Bait boat fish are taken aboard almost instantly from a static or slow moving vessel so it was thought that their condition might be better for tagging. This could be related to the tagging methods, for example if fish were placed in live bait tanks onboard the bait boat vessels prior to tagging.

The size range of 65 – 74cm FL for conventional released fish with the highest probability of recapture corresponds to 2 and 3 year old fish. The average period of liberty observed from the edited conventional data set for fish in this size class was 309 days with an average growth specifically for this size range of 0.305 mm per day so one would reasonably expect a significant proportion of these fish to be recaptured at a size of about 9.4 cm greater than when they were released or in the 65 – 74cm and 75 – 84cm FL size classes. These sizes correspond to age 2 and 3 fish which are the principal target of the Bait boat and Troll fleets (Ortiz de Zarate *et al*, 2007).

Examining the lengths at recapture from the conventional data set a relatively high proportion of fish, 29%, were in the 75 – 84cm size class, while a higher proportion, 35%, were in the 65 – 74cm FL size class. In the dummy tagging trial 50% of recaptured fish were in the 65 – 74cm when initially released, although just 27% of all released fish were in this size range.

In analyzing the conventional data set, a number of factors such as the skill or qualification of the personnel carrying out tagging, or the level of promotion for tag returns for a given period, have not been documented or analysed, although they could have a significant effect on the analysis. It is hoped, however, that limiting the data set to just one nation, and 2 fishing methods over a relatively restricted time period as assisted in removing some of the bias associated with these unknowns.

Recent advances in pop up satellite tagging technology have resulted in pop up tags, which are roughly half the size of the originals, which enables them to be used on smaller species. These smaller pop ups have yet to be tested on albacore tuna, but as the tags remain relatively large compared to the size of the fish, attachment periods of up to several weeks may therefore be expected compared to several months for larger species such as bluefin tuna. Consequently, archival tagging (implantable) is still the best option for obtaining long term data sets on the behavior of albacore tuna.

The results of the present study suggest that, funds permitting, it would be feasible to carry out an archival tagging programme for albacore tuna in the North East Atlantic. Tags deployed on fish released from an Irish vessel were recovered by Institutes in Spain, the Basque Country, France and the Canary Islands, so the system of tag recovery across several nations worked well. Also, the relatively long periods of liberty, large distances travelled and comparable growth rates to conventional tagging studies, suggest that the implantable tagging technique does not hinder the behavior or physiology of albacore tuna.

In addition the results of the analysis of the conventional data set suggest that it should be possible to boost recapture rates of tagged fish by tagging fish under optimal conditions as predicted by the model. The model predicted that fish in the 65 – 74cm FL size class were between 2.5 and 5.5 times more likely to be recaptured than fish outside this size class under 85cm FL. These figures were supported by the basic statistics of the dummy tagging programme which showed that 50% of recaptures were in this size class when released despite just 27% of all fish released occurring in this size class. It should therefore be possible to boost the recapture rate of archival tagged fish by a factor of 2 from 2.27% to 4.54%. In addition although not proven in the current study, it is reasonable to expect that tagging earlier in the season close to the Spanish coast would provide a greater opportunity for fish to be recaptured, as they migrate along areas of concentrated fishing effort, as the fishing season unfolds. Taking these factors into account it should be possible to boost the recapture rate to at least 5% after 2 – 3 years.

Although North Atlantic fisheries for albacore tuna have remained relatively stable compared to other tuna stocks, the stock is considered to be overfished and the 2008 total allowable catch (TAC) for European Community (EC) fishing vessels has dropped by over 4000 tonnes to 30200 tonnes (ANON, 2008a). The albacore fishery was worth roughly €60m at the first point of sale to EC vessels in 2007, which accounted for approximately 85% of total albacore tuna landings in the North Atlantic. Based on the results of the present study, an authentic archival tagging programme with an objective of 10 recovered tags would require 200 tags to be deployed. Taking factors such as vessel hire, personnel etc. into account this would cost in the region of €250,000 to implement which equates to around 0.33% of the annual value of EC landings. This would undoubtedly provide important information towards the management of this highly economically important fishery and would be cost efficient given the proposed cost of the research in relation to the total value of the fishery. In addition ICCAT has recommended that tagging programmes for Atlantic albacore stocks should be initiated and promoted (ANON, 2008b). The predominance of several EC nations in the fishery and the substantial investment required suggests that funding should ideally be provided by the EC to initiate an archival albacore tagging programme in the North East Atlantic.

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Table 1. Details of dummy archival tag recaptures (*- estimated).

Archival Tag No.	Date	Lat. Deg.	Lat. Min.	Long. Deg.	Long. Min.	Length (cm)
Release						
320	16/07/2005	47	31.23	8	56.30	76
327	16/07/2005	47	30.19	8	53.44	64
374	18/07/2005	47	54.25	9	50.32	67
342	17/07/2005	47	58.39	10	0.61	65
438	20/07/2005	47	55.78	9	38.38	58
442	20/07/2005	47	57.63	9	43.60	67
483	22/07/2005	47	57.01	10	0.22	69
617	24/07/2006	47	24.23	11	40.73	64
Recapture						
320	07/07/2006	45	22.00	6	19.00	84
327	21/07/2007	44	30.00	3	50.00	80
374	18/09/2005					
342	31/10/2006*					74
438	21/07/2007*	43	47.00	3	47.00	
442	23/05/2007	28	31.00	17	38.00	89
483	10/10/2007	49	16.00	11	54.00	89
617	09/09/2007	47	47.00	10	0.00	75

	Days at Liberty	Distance (Km)	Growth (FL, cm)
320	356	453	8
327	735	740	16
374	60		
342	471*		9
438	731*	928	
442	672	2911	22
483	810	306	20
617	412	197	11

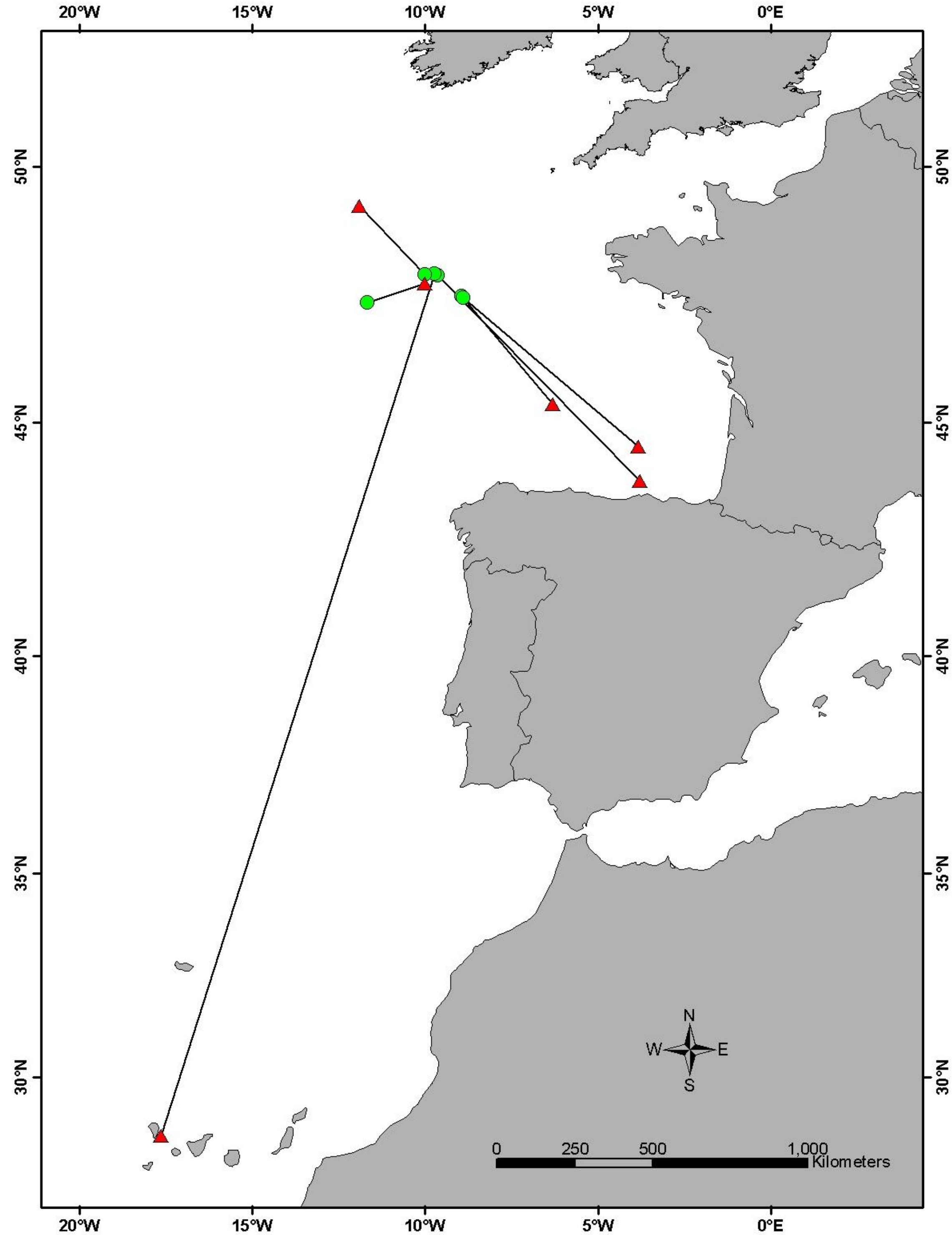

Figure 1. Release (Green Circles) and recapture (Red triangles) locations of dummy archival tagged albacore tuna

Table 2. Albacore tag releases by year and gear type for the North East Atlantic

Year	BB	RR	SP	TR	TL
1976				233	233
1977				39	39
1978				141	141
1979	4			29	33
1980	2			221	223
1981				3	3
1982	3				3
1983	1			277	278
1984	1			192	193
1985				139	139
1986	106			103	209
1988				489	489
1989	2969			40	3009
1990	4515			57	4572
1991	4113			187	4300
1994				1	1
2001		10			10
2002		80			80
2003	2	523	8	1	534
2004		108	18		126
2005			328	1	329
2006			2124	2	2126
Total	11716	721	2478	2155	17070

Table 3. Results of Binary Logistic analysis on Bait Boat and Troll tag release data from 1983 - 1991

Parameter	Estimate	S.E.	t-ratio	p-value
1 CONSTANT	-1.932	0.186	-10.383	0.000
2 LENGTHCLASS2_1	-0.869	0.157	-5.544	0.000
3 LENGTHCLASS2_2	-0.482	0.143	-3.375	0.001
4 LENGTHCLASS2_3	-0.655	0.265	-2.475	0.013
5 LENGTHCLASS2_4	-0.576	0.473	-1.216	0.224
6 RGEARCODE$_BB	-1.023	0.151	-6.789	0.000
7 EFFORTCAT (Low)	-0.602	0.229	-2.621	0.009

		95.0 % bounds	
Parameter	Odds Ratio	Upper	Lower
2 LENGTHCLASS2_1	0.419	0.570	0.308
3 LENGTHCLASS2_2	0.618	0.817	0.467
4 LENGTHCLASS2_3	0.519	0.873	0.309
5 LENGTHCLASS2_4	0.562	1.422	0.222
6 RGEARCODE$_BB	0.359	0.483	0.267
7 EFFORTCAT$ (Low)	0.548	0.859	0.349

Log Likelihood of constants only model = LL(0) = -1861.432
2*[LL(N)-LL(0)] = 62.659 with 6 df Chi-sq p-value = 0.000
McFadden's Rho-Squared = 0.017

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	9.9478	13	0.698
Deviance	11.4446	13	0.574
Hosmer-Lemeshow	2.5393	2	0.281

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

Value	1		0		
Group	Obs.	Exp.	Obs.	Exp.	Total
1	72	81.8	3792	3782.2	3864
2	203	198.5	6259	6263.5	6462
3	91	82.1	1737	1745.9	1828
4	56	59.6	786	782.4	842

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	2423182	45.7	Somers' D	0.21
Discordant	1290788	24.3	Goodman-Kruskal Gamma	0.30
Ties	1592258	30.0	Kendall's Tau-a	0.01
Total	5306228	100.0		