Where have the tags gone?
SImulatioN of TAGs (SINTAG): A simple model to estimate the number and size of tunas tagged by the RTTP-IO that are currently still alive.

By

P. A. de Bruyn*, H. Murua* and A. Fonteneau†

*AZTI Tecnalia
Herrera Kaia, Portualde z/g
20100 Pasaia
Basque Country, Spain

† IRD Scientist
CRH, BP 171
34203, Séte, Cedex
France

Abstract

The large scale Regional Tuna Tagging Programme in the Indian Ocean (RTTP-IO) has reported a 14% return rate of the 168.000 tuna tagged between 2005 and 2007. Approximately 96% of these returns have been reported from the purse seine fishery. This has lead to speculation that the tagged tuna have not yet reached sizes at which they could be caught by longliners (bigeye and yellowfin) or by the baitboat fishery (skipjack) A simple exponential decay and growth model has, however, indicated that this may not be the case, and tagged individuals should be available to these fisheries. It would thus appear that tagged tuna are not being reported by the longline and baitboat fisheries and an effort should be made to increase the level of tag reporting in those fleets in order to maximise the usefulness of the data obtained from the RTTP-IO.

Résumé

Le grand programme de marquages de thons qui vient de s'achever dans l'Océan Indien (RTTP_IO) a permis la recapture de 14% des 168.000 thons qui ont été marqués de 2005 à 2007. Environ 96% de ces recaptures ont été rapportées par les senneurs, ceci pouvant être due au fait que thons marqués à des petites tailles n'était pas encore capturables par les palangriers (albacore et patudos) ou par les canneurs (listaos). Un simple modèle simulant la croissance et la mortalité des thons marqués survivants a donc été mis au point, et ce modèle montre que les thons marqués ont actuellement des tailles auquelles ils pourraient être capturés par ces pêcheries.

Ceci confirmerait l'hypothèse qu'il y aurait une sous déclaration par les canneurs et les palangriers de leurs recaptures de thons marqués. Un effort pour améliorer le retour de ces marques est donc recommandé afin de valoriser au mieux les résultats acquis par le programme de marquages.

1 Introduction

Large-scale tagging is necessary for an efficient assessment of all tuna stocks. Tag release-recapture experiments are commonly used to estimate parameters, such as growth, mortality, and population size, of exploited fish stocks (Beverton and Holt, 1957; Seber, 1973). In the Indian Ocean, however, tagging has historically only been carried out in the Maldives (Adam and Sibert 2001). As the Indian Ocean has increasingly become an important tuna fishing region, particularly for tropical tuna species, it was strongly recommended in 2000 by the IOTC that a large scale tagging project be conducted as soon as possible in the region.

The Regional Tuna Tagging Project – Indian Ocean (RTTP-IO) was requested by the Indian Ocean Tuna Commission (IOTC) scientists to address the issue of the state of the stocks of the three main tropical tuna species: yellowfin tuna (*Thunnus albacores*), bigeye (*T. obesus*) and skipjack (*Katsuwonus pelamis*). The project was funded by the 9th European Development Fund (EDF) with technical Supervision of the Project provided by the IOTC, and was based in the Seychelles.

This large-scale tagging of tropical tuna species was carried out under the RTTP-IO between May 2005 and August 2007. During this time, 168,163 tuna with tags were released including 34,570 bigeye, 54,663 yellowfin and 78,324 skipjack. By June 9th 2008, the RTTP-IO reported that they already had 24 147 reported recoveries in its database, indicating a 14.4% recovery rate. Full details of the tagging data (numbers released by species/gear etc., as well as all data pertaining to recaptures) are provided by Hallier (2008). The RTTP-IO also noted that the number of tuna tagged and the number of tags returned were very similar between species. The rate of return has not been similar between fishing gear groups, however, with 96.3 % of all recoveries coming from purse seine vessels.

This large discrepancy in tag reporting rates between fisheries has prompted the IOTC to request an investigation into its possible causes. In the last Working Party of Tagging Data Analysis (WPTDA) it was suggested that the reason for the lack of tag reporting from the longline fishery is due to the fact that the majority of bigeye and yellowfin tuna tagged, were and are still below the size caught by this fishery. This was also suggested to be the case for the baitboat fishery with regards to skipjack tuna. As a result, the WPTDA decided to investigate the development of the three species tuna tagged using a combined growth, exponential decay model in order to determine:
a) if any of the tagged tunas have grown to a size at which they may be available to the aforementioned fisheries, and
(b) if this is found to be the case, how many of these surviving tagged tunas could still be available to the aforementioned fisheries.

These estimated numbers of surviving tuna at given sizes are also estimated by Multifan-CL and other statistical models, but there are various benefits to estimating these parameters directly using ad hoc simulation models. These are: (1) to easily and quickly obtain the estimated numbers and sizes of tagged survivors, (2) to easily introduce new parameters in the model (for instance growth, natural and fishing mortality)

2 Models

The purpose of the SINTAG model is to simulate the decay and growth of cohorts of tunas tagged within a given period of time (in this case 2 years), with each fish exhibiting an assumed growth, and each cohort suffering a natural and a fishing mortality. The present simulated fishing mortality is simply the number of recovered tags, although an alternate fishing mortality hypothesis, (for instance vector of F at age estimated by an assessment model) could of course be easily introduced as an alternate hypothesis).

Data included in the model were provided by the RTTP-IO. All tag releases of bigeye, yellowfin and skipjack tuna were extracted from the RTTP-IO database. Any data classified as of poor quality for the WPTDA, or for which there was missing information (such as release date, or release size), was excluded.

Initially, the model simulated the dynamics of the tagged individuals from the first month of tagging (May 2005) until the end of August 2007, the date at which the last tagged individuals were released. In all cases, intervals **t** of the model were measured in months. The dynamics of the model are described by the following equations:

For the Initial year of the model (May 2005):

$$N_{l,t=1} = T_{l,t=1} \qquad (1)$$

Where: $N_{l,t=1}$ is the number of tagged individuals of length l in the first time period of the model,

$T_{l,t=1}$ is the number of tagged individuals of length l released in May 2005.

Between June 2005 and August 2007:

$$N_{l,t} = N_{l-1,t-1} \times e^{(-M((t_1-t_2)/12)} + T_{l,t} - R_{l,t} \qquad (2)$$

Where: $N_{l,t}$ is the number of tagged individuals of length l at time t,

$N_{l-1,t-1}$ is the number of individuals from a smaller length class in time t - 1 calculated to have grown to length l by time t using the growth equations below,

M is the instantaneous natural mortality,

$T_{l,t}$ is the number of newly tagged and released individuals of length l at time t,

$R_{l,t}$ is the number of reported recaptures by any fishery of tagged individuals of length l at time t.

For the purposes of this model, Z was replaced with M in equation 1 (Table 1), as the number of tagged individuals removed from the population was accounted for using the term $R_{l,t}$ .M was assumed to be constant across age-groups and years .

From September 2007 until October 2008:

$$N_{l,t} = N_{l-1,t-1} \times e^{(-M((t_1-t_2)/12)} - R_{l,t} \qquad (3)$$

Equation 3 was modified to reflect the fact that no new tagging occurred after August 2007, by removing (the $T_{l,t}$ term). The present final year and month included in the model was October 2008, but this date could easily be expanded in time in order to allow projected estimations of the numbers and sizes of tagged survivors for each species

Growth of the tagged individuals was modelled using the equations proposed by Eveson and Million (2008) but re-parameterized by Eveson (2008) subsequent to the IOTC working party on tagging data analysis meeting (WPTDA) in June 2008.

For skipjack tuna, a simple Von Bertalanffy growth function was assumed:

$$\Delta L = (66 - L)(1 - e^{-0.498\Delta t}) \qquad (4)$$

For yellowfin and bigeye tuna, a VB log k growth function (Laslett *et al.* 2002) was assumed, where:

$$l(a) = L_\infty f(a - a_0; \theta) \qquad (5)$$

L_∞ is asymptotic length and *f* is a monotone increasing function with parameter set $\{a_0, \theta\}$ that equals 0 when $a = a_0$. θ and *f* can be defined as follows:

VB log k: $\theta = \{k_1, k_2, \alpha, \beta\}$ and

$$f(a - a_0; \theta) = 1 - \exp(-k_2(a - a_0)) \left\{ \frac{1 + \exp(-\beta(a - a_0 - \alpha))}{1 + \exp(\alpha\beta)} \right\}^{-(k_2 - k_1)/\beta} \qquad (6)$$

The parameter estimates included in equation 6 are presented in table 2.

The simulated sizes of the tagged tunas have also been compared to the typical sizes caught by the various fisheries and the catch at size data from the IOTC database were used to calculate the length classes targeted by the longline fisheries for yellowfin and bigeye tuna and the baitboat fishery for skipjack tuna. The catch at size data were averaged between 2000 and 2006. The size frequencies of the tagged tuna at release are also provided, and they are independent of release date. The numbers of tagged tuna released presented in the figures below are less than the official number of released tuna mentioned above, as all data entries that were judged to be unreliable were removed for the purposes of this study, as explained above.

3 Results

The projections for the tagged yellowfin are presented in Figure 1. It is clear from these projections that by the time this study was initiated in June 2008, the predicted lengths of the tagged individuals fell within the size distribution targeted by the longline fishery. This is also the case for the tagged bigeye tuna (Figure 2), although the distribution of predicted tagged bigeye lies to the left of the size distribution observed for the longline fishery. For skipjack tuna, the size distribution observed for the Maldivian baitboat fishery is typically bimodal. The predicted distribution of the tagged skipjack lies within the right modal distribution of the observed catch of skipjack by the baitboat fishery (Figure 3).

4 Discussion

The method used by SINTAG to estimate the present number and sizes of tagged tunas, taking into account their growth and mortality is clearly a quite simplistic approximation, but also an interesting attempt to estimate this fundamental information. The model assumes that all recaptured tuna have been reported and hence does not include an F estimate in the model, as it appears that recoveries are not fully reported by various fisheries.. This almost certainly will affect the total numbers of surviving tagged tuna that may be available to the various fisheries. Should F have been included, tag reporting rates would also need to be included in the model, increasing its complexity. This would have been slightly problematic when one considers that the point of this study was to investigate why there is a perceived problem with tag reporting rates in the first place. It was thus decided that further complexity was beyond the scope of this simple study, but can be included in the future, should this work be continued. These models do, however, show that theoretically at least, tagged tuna should be available to these fisheries. It is thus not clear from a biological aspect why there is such a discrepancy in tag reporting rates between fisheries.

The model also indicates that there should still be fairly large numbers of tuna at liberty. As the return rate for tagged tuna has been in excess of 14%, one could reasonably expect that some of these tuna should have been caught by the longline and baitboat fisheries. This of course is dependant on the assumption that once the tuna have been tagged and released, they have an equal probability of being recaptured by all the fisheries targeting tuna in the Indian Ocean. As the majority of tuna were tagged and released in areas most commonly targeted by purse seine fisheries (Hallier 2008), this may partly explain the high reporting rate from this fishery relative to the others. Further modelling regarding tuna movement and times at liberty may clarify this issue somewhat.

Given that it is important to have good estimates of tag reporting rates when inferring exploitation rates and other mortality rates from tagging experiments (Cadigan and Brattey 2006), it is of vital importance that the reason for the low reporting rates from the longline and baitboat fisheries is determined. Should it be found that the capture of tagged individuals by these fisheries is not being reported, it is crucial that this situation be rectified. The RTTP-IO has resulted in a wealth of information being obtained on tuna in the Indian Ocean region, but every effort must be made to maximise its quality and usefulness in order to facilitate the use of this data in the management of tuna species in the region.

References

Adam, M. S. and Sibert, J. R. 2001. Population dynamics and movements of skipjack tuna (*Katsuwonus pelamis*) in the Maldivian fishery: analysis of tagging data from an advection-diffusion-reaction model. *Aquat. Living Resour.* **15.** 13–23

Beverton, R. H. J., and Holt, S. J. 1957. On the dynamics of exploited fish populations. *Fish. Invest. Ser. II, Mar. Fish. G.B. Minist. Agric. Fish. Food.* **19**. 533 p.

Cadigan, N. G. and Brattey, J. 2006. Reporting and shedding rate estimates from tag-recovery experiments on Atlantic cod (*Gadus morhua*) in coastal Newfoundland. *Can. J. Fish. Aquat. Sci*. **63**. 1944- 1958.

Eveson, J. P. and Million, J. 2008. Estimation of growth parameters for yellowfin, bigeye and skipjack tuna using tag-recapture data. Unpublished IOTC working paper **IOTC-2008-WPTDA-07.** Victoria, Mahe, Seychelles 33pp

Eveson, J. P. 2008. Updated results from applying the Laslett, Polacheck and Eveson (LEP) method to the data agreed on at the IOTC WPTDA, 30 June – 4 July 2008. Unpublished IOTC working paper. Victoria, Mahe, Seychelles 7pp

Hallier, J-P. 2008. Status of the Indian Ocean Tuna Tagging Programme- RTTP-IO. Unpublished IOTC working paper **IOTC-2008-WPTDA-10.** Victoria, Mahe, Seychelles. 40pp.

Laslett, G.M., Eveson, J.P., and Polacheck, T. 2002. A flexible maximum likelihood approach for fitting growth curves to tag-recapture data. *Can. J. Fish. Aquat. Sci.* **59**: 976-986.

Seber, G. A. F. 1973. The estimation of animal abundance and related parameters. Charles Griffin. London. 654 p.

Table 1: Natural mortality estimates for the three tuna species included in the model
.

Species	Instantaneous natural mortality
Yellowfin tuna	$0.8.y^{-1}$
Bigeye tuna	$0.6.y^{-1}$
Skipjack tuna	$1.2.y^{-1}$

Table 2: Parameter estimates for VB log k model

Species	L_∞	k_1	k_2	α	β	a^0
YFT	146	0.1334	0.905	4.1228	10.9654	-1.42
BET	160	0.071	0.4207	5.6033	2.999	-3.09

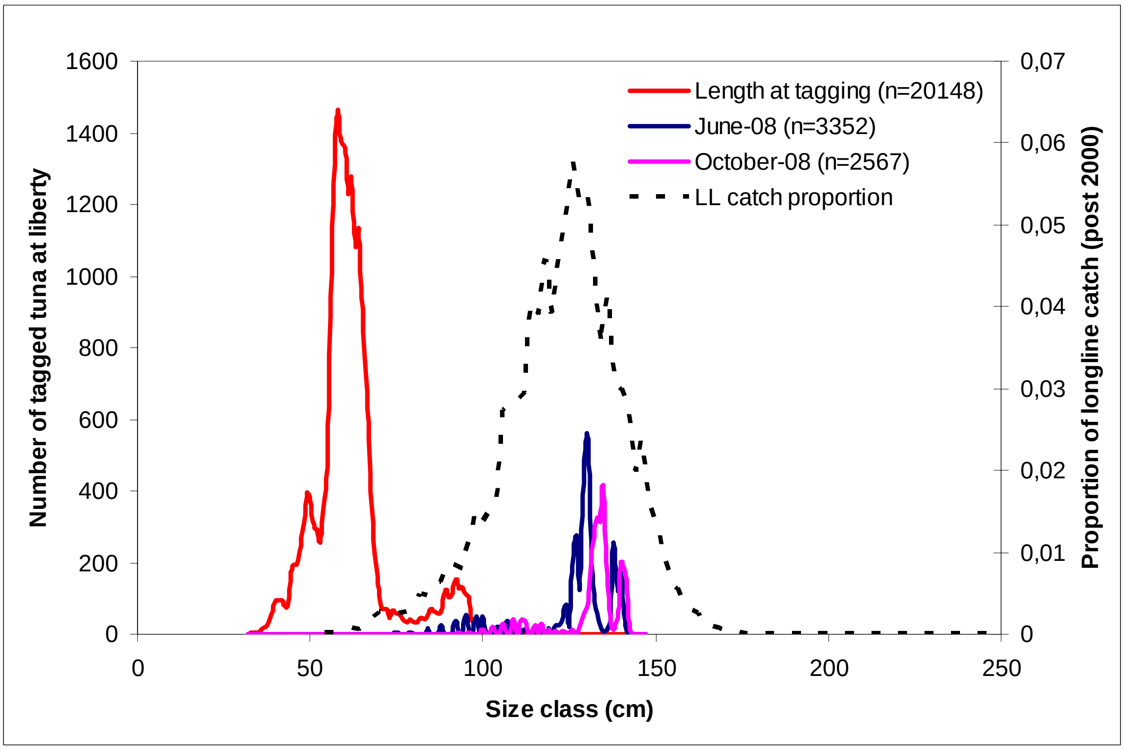

Figure 1: Numbers and size frequency of **yellowfin** tuna tagged by the RTTP-IO and observed size distribution of yellowfin tuna caught by the longline fishery in the Indian Ocean between 2000 and 2006. Solid lines are plotted on the primary y axis, while the dotted line is on the secondary y axis.

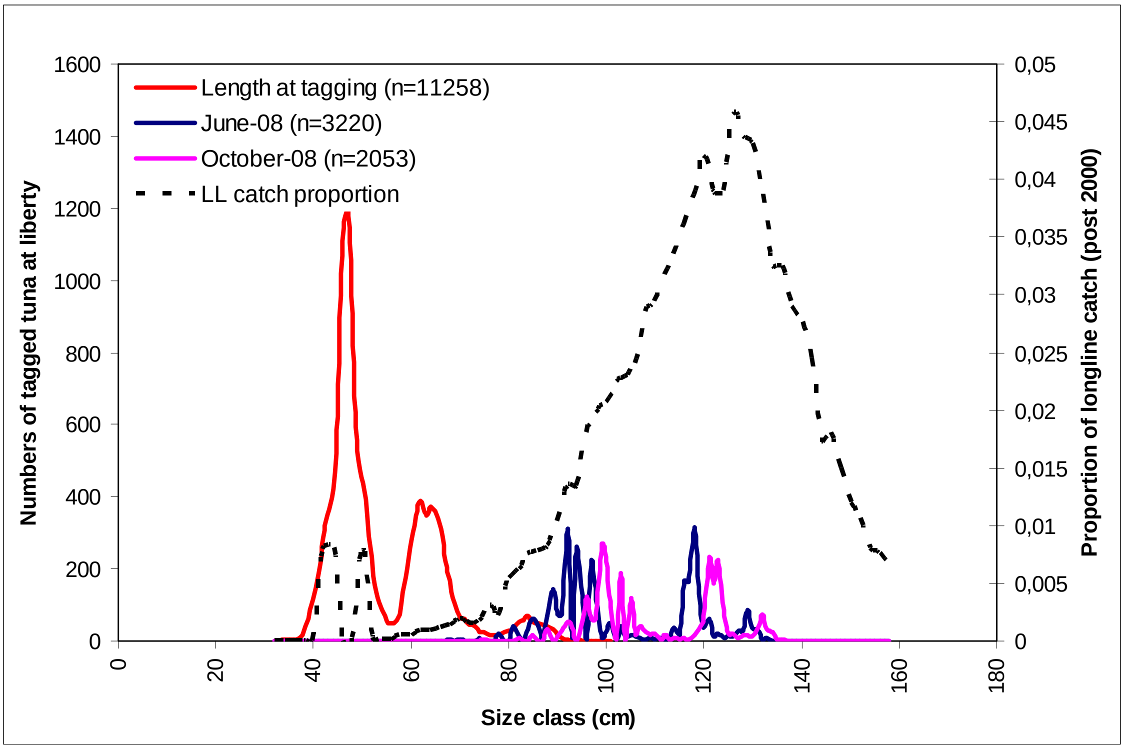

Figure 2: Numbers and size frequency of **bigeye** tuna tagged by the RTTP-IO and size distribution of bigeye tuna caught by the longline fishery in the Indian Ocean between 2000 and 2006. Solid lines are plotted on the primary y axis, while the dotted line is on the secondary y axis.

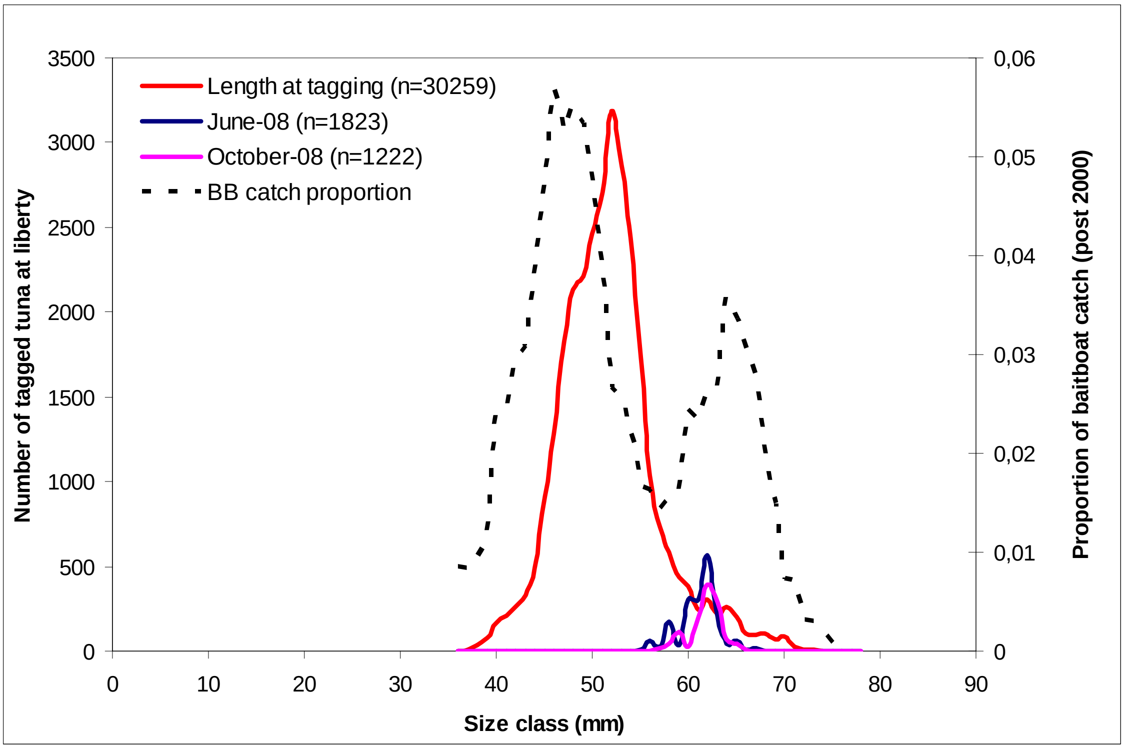

Figure 3: Numbers and size frequency of skipjack tuna tagged by the RTTP-IO and observed size distribution of skipjack tuna caught by the baitboat fishery in the Indian Ocean between 2000 and 2006. Solid lines are plotted on the primary y axis, while the dotted line is on the secondary y axis.