Fisheries Research 163 (2015) 98–105

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Tag shedding by tropical tunas in the Indian Ocean and other factors affecting the shedding rate

Daniel Gaertner[a,*], Jean Pierre Hallier[b]

[a] IRD—UMR EME, CRH, BP 171, 34203 Sete Cedex, France
[b] Regional Tuna Tagging Project—Indian Ocean (RTTP—IO), Victoria, Seychelles

ARTICLE INFO

Article history:
Received 25 June 2013
Received in revised form 22 February 2014
Accepted 25 February 2014
Available online 23 March 2014

Keywords:
Tagging data
Shedding rate
Beta-binomial model
Bayesian model averaging
Tropical tunas
Indian Ocean

ABSTRACT

A key objective of the Regional Tuna Tagging Project—Indian Ocean was to estimate tag-shedding rates, Type-I (immediate tag shedding) and Type-II (long-term tag shedding). To assess this, a series of double-tagging experiments (26,899 double tags released with 4555 recoveries) were conducted as part of the broader tagging program. After omitting data from tags placed by less experienced taggers, the results of our analyses did not show any evidence that individual differences between taggers (i.e., a tagger effect) impacted estimates of tag-shedding rates. However, it was shown that the probability of retaining the second tag (inserted in the left side of the fish) was larger than retaining the first tag (inserted in the right side, i.e., the side typically tagged in single-tagging experiments). We used a Bayesian model averaging approach to account for model uncertainty in the estimates of the parameters α and L used to calculate the probability of tag retention $Q(t) = \alpha\ e^{-(L\,t)}$ for the right tag. The parameter estimates were $\alpha = 0.993$ and L (per year) = 0.030 (skipjack); $\alpha = 0.972$ and L (per year) = 0.040 (yellowfin); and $\alpha = 0.990$ and L (per year) = 0.021 (bigeye). These results agree with estimates obtained by other large-scale tropical tuna tagging projects. We showed that tag loss has a moderate impact on the underestimation of the exploitation rate (bias = 2–6% depending on the tuna species). However, non-reporting leads to a bias of around 7% when using the high reporting rate estimate of purse seiners. Finally, tag shedding (specifically Type-II shedding) modified the individual weights of the samples of recaptures. Consequently, the total instantaneous mortality estimates (Z; calculated from mean times-at-large) were reduced by a range of 1–3%.

1. Introduction

Mark-recapture techniques can facilitate the collection of useful information for stock assessments, such as stock structure, growth and mortality rates, gear selectivity, and migration patterns. Consequently, tagging studies have become one the key tools used by tuna Regional Fisheries Management Organisations (RFMOs) to improve understanding of how populations are spatially structured and the effects of fishing on these populations. Integral to the use of tagging data are standardization models, such as tag-attrition models for single release events (Kleiber et al., 1987; Hampton, 1997) or Brownie models (derived from bird-banding studies) for multiyear studies (Brownie et al., 1985; Hoenig et al., 1998; Polacheck et al., 2010). The results of tagging studies can, however, be compromised if tags or data are lost (i.e., through tag shedding and non-reporting). Both occurrences can lead to underestimations in tag-return rates, which create a negative bias in fishing mortality estimates, rates of fishery interactions, and tuna movements. Ultimately, this leads to biased estimates of stock status. Thus, the objective of this paper is to update preliminary estimates of tag-shedding rates by tropical tuna in the Indian Ocean (Gaertner and Hallier, 2008, 2009).

There are two types of tag losses (Wetherall, 1982; Hampton and Kirkwood, 1990): Type-I losses, which reduce the number of tags initially put out (immediate tag shedding, immediate tagging mortality, and non-reporting), and Type-II losses which occur steadily over time (natural mortality, fishing mortality, permanent emigration, and long-term tag shedding). The current paper is only estimating the Type I and II tag shedding components of total losses. Immediate tag shedding and immediate tagging-induced mortality rates can be estimated by observing tagged fish under controlled laboratory conditions or in field cages (Pollock and Pine, 2007). However, post-release mortality estimates derived under these circumstances may be biased: in general, unlike wild fish, captive

* Corresponding author. Tel.: +33 499 573231; fax: +33 499 573295.
E-mail addresses: daniel.gaertner@ird.fr (D. Gaertner), jean-pierre.hallier@ird.fr (J.P. Hallier).

http://dx.doi.org/10.1016/j.fishres.2014.02.025
0165-7836/

Table 1
Number of double-tagged tuna (released in good condition, see Section 2.1) and the percentages of recaptures made (by species) between 2006 and 2012 with two tags (Both) and one tag (Right or Left) for bigeye (BET), skipjack (SKJ), and yellowfin (YFT).

BET				SKJ				YFT			
Released											
7310				9309				10,280			
Recaptured (%)											
Total	Both	Right	Left	Total	Both	Right	Left	Total	Both	Right	Left
15.84	15.14	0.25	0.45	15.65	14.94	0.32	0.39	18.87	16.81	0.90	1.16

fish are not affected by post-release predation. On the other hand, the act of restraining fish in confined conditions can have lethal or sublethal effects. An alternative approach to estimating mortality that is commonly used is double-tagging experiments in which a fish is tagged with two tags simultaneously. Double tagging can also be used to estimate tag-shedding rates by identifying fish that have lost a tag.

In general, shedding rates cannot be estimated from tag-return data directly. Consequently, different methods have been proposed to estimate shedding rates from double-tagging experiments. To maximize the accuracy of these estimates, it is crucial to have a firm understanding of the functioning of the range of other variables known to impact tag shedding. The Regional Tuna Tagging Project—Indian Ocean (RTTP—IO), which focuses on tropical tuna in the Indian Ocean, has already examined some of these variables. For example, there is no evidence, or it remains unclear, whether factors such as tag length (11 cm and 14 cm length tags) or tag position (right side versus left side of the fish) influence the rate of tag returns in RTTP-IO double-tagging experiments (Gaertner and Hallier, 2008). However, multiple taggers have been used over the duration of the program, and tag-return rates are known to vary substantially between taggers. Therefore, in this context, it is desirable to estimate how shedding rates vary among taggers.

Consequently, this study focused on (1) an analysis of the tagger effect and other explanatory variables that were hypothesized *a priori* to influence tag loss, (2) comparing the constant-rate and time-varying approaches to modeling tag-shedding rates, (3) an analysis of how the insertion position of the tag affects shedding rates, and (4) an investigation into the consequences of ignoring tag shedding and non-reporting on the estimates of exploitation rate and total instantaneous mortality.

2. Material and methods

2.1. Data

Over the duration of the RTTP-IO, a number of different tag types (e.g., conventional, archival) and tag colors have been used. Tag colors are used to indicate the presence of other tag types. Conventional tags are traditionally yellow, but a white version is used if oxytetracycline is also injected into the fish, and a red version is used when an additional archival tag is inserted. In the RTTP-IO, the single- and double-tagging experiments have been alternately performed and always used the conventional yellow ‘spaghetti’ tags. Our analysis focused on data collected from double-tagging experiments. We used only updated tagging data, which is comprised of tag recaptures reported from January 15, 2006 up until June 2012 for double-tagging experiments conducted onboard RTTP-IO bait boats. These experiments focused on the three main species of tropical tuna, yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), and skipjack (*Katsuwonus pelamis*). Data for fish that were in a sub-optimal condition, including those that showed signs of bleeding, had tail or mouth damage, were dropped on the deck, hit the side of the boat, or had shark bite injuries, were omitted from this analysis. This ensured that our analysis only considered fish that were in good condition at release. In addition, we further restricted the data to only include records where the species were clearly identified at both release and recovery (for more information on how tag data are collected at release and recovery, see Hallier (2004) and Athayde et al. (2006)). Once these data were omitted, the data set analyzed in this paper included a total of 26,899 double-tagged release records and 4555 recoveries (thus far), which includes 329 records of fish that have lost one of their tags (Table 1).

To analyze the potential tagger effect on the shedding rate, double- and single-tag recoveries were pooled by tagging cruise and by tagger (hereafter referred to as a ‘batch’). The proportion of single- and double-tagged fish can vary between batches and it is important to note these differences as they can potentially lead to biases in tag-shedding estimates (Hearn et al., 1991). Further, to avoid the high variability in shedding rates caused by low sample sizes, batches with <10 recoveries were omitted.

Recapture dates are needed to calculate the number of days at sea. When the exact date was lacking from the tagging data set, the date of recapture was estimated. This was done by averaging the dates of the sets in which the recaptured tag was most plausibly caught by purse seiners.

2.2. Methods

2.2.1. Estimate of a potential tagger effect on the shedding rate

Although a more sophisticated approach to evaluate differences between individual taggers has been proposed (Xiao, 1996), in this study, we assumed that the proportion of double-tagged fish recovered with only one tag is a linear combination of three categorical variables and one continuous variable. The categorical variables are the species S (yellowfin, bigeye, or skipjack), the tagger identification T, and the cruise identification C. The continuous variable is the tagger experience E, which is gained by each tagger over the length of the tagging program. Tagger experience was expressed as the cumulative number of fish tagged (single and double tags; all species) that were previously released by a tagger t, at the beginning of a cruise c. Consequently, to determine if shedding rates differed between taggers, we fit several candidate models, using different combinations of explanatory variables (assumed *a priori* to influence tag shedding, e.g., a cruise effect or the effect of a tagger's experience).

Owing to the clustered structure of the tagging data, it is logical to assume that the shedding rate y has extra-binomial variation. One way to account for this overdispersion is to use a probability model that applies a more general distribution, i.e., a beta-binomial model. The beta regression model is based on an alternative parameterization of the conventional beta density, and includes the variate mean μ, and a precision parameter ϕ. The beta density can thus be expressed as:

$$f(y;\mu,\phi)=\frac{\Gamma(\phi)}{\Gamma(\mu\phi)\Gamma((1-\mu)\phi)}y^{\mu\phi-1}(1-y)^{(1-\mu)\phi-1},$$

where $0<y<1$, $0<\mu<1$ and $\phi>0$ (Ferrari and Cribari-Neto, 2004).