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Tag Shedding by Tropical Tunas in the Indian Ocean: explanatory analyses and first results.

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Introduction

Estimate of tag-shedding is required for an estimation of fishing and natural mortality rates from tagging data. Tag shedding is of two types (Wetherall, 1982):
-Type-1 shedding includes immediate tag shedding, immediate tagging-induced mortality and failure to report recovered tags
-Type-2 shedding includes continuous tag shedding/mortality attributable to the tag, emigration away from the fishing ground, etc

Tagging data are commonly used to estimate mortality rates with the aid of tag attrition model, such:

$$\hat{r}_{ij} = (1 - \rho_i)\, T_i \, \frac{F_j}{Z_{ij}} \left[1 - \exp\left(-Z_{ij}\right) \Delta_t \right] \exp\left(- \sum_{k=1}^{j-1} Z_{ik}\, \Delta_t \right)$$

However, excepted for the comparison of efficiency between different types of tag (Gaertner et al, 2004), type-1 (ρ) and type-2 (in $Z = F + M + \lambda i$) shedding rates cannot be estimated in general, directly from tag-return data. As a consequence, different methods have been proposed for estimating shedding rates using data from double tagging experiments. In this paper we explore briefly how some factors may influence the return rate in tropical tunas, then we estimate the shedding rate based on double tagging experiments conducted in the Indian Ocean between 2006 and 2008.

Data

Different types of tags have been used during the Regional Tuna Tagging Project – Indian Ocean (RTTP-IO). However, only conventional « spaghetti » tags are considered in this study (i.e., red and white tags indicating archival tags and injection of oxy-tetracycline for growth studies, respectively, were omitted). The remaining conventional tags were of 2 different lengths: 11 cm (labelled with « CC » in the first two digits of the identification number) and 14 cm (identification beginning with « EE » or with « KK »); Length was the unique difference characteristic between these two types of tags. In the case of double tagging experiments (conducted alternatively with simple tagging operations) tags originally inserted in the right side of the fish were identified by even numbers and tags inserted at the left side were coded with odd numbers.

Because recapture dates are needed to calculate days at sea, when this information was lacking from the tagging data set, the date of recapture was estimated in the following decreasing order:

1) Performed as: MinOfD + (MaxOfD-MinOfD)/2, if MinOfD and MaxOfD are available and if (MaxOfD-MinOfD)/2 > date of tagging. MinOfD and MaxOfD represent the minimal and the

maximal date, respectively, among a subset of the most plausible dates of recaptures (e.g., based on all the sets from which the tagged fish was assumed to be caught)
2) Performed as Date of tagging + (MaxOfD-Date of Tagging)/2, if MoyOfD < Date of Tagging and if MaxOfD available,
3) and, substituted by the return date of the tag to the local scientists, or to the RTTP-IO staff (obviously, the most imprecise information since some delay may exist between the date of recapture at sea and the date at which the tag was reported)

To assess the accuracy of these rules of substitution, we use a subset of the tagging data for which the date of recapture is known. From the comparison between the true date of recapture and the different « candidate » dates (figure 1), we observe that the average date (case 1 and 2) of the plausible sets, does not produce any apparent bias (notice that for convenience the frequency axis was log-transformed) even if there is some variability (upper part of figure 1). In contrast, when there was no alternative that using the return date (case 3), we may expect a systematic bias (lower part of figure 1). As the median of this difference was estimated at 18 days, we subtracted the return date by 18 each time substitution rule n° 3 has been applied.

Method

Explanatory analysis of the factors that may affect the return rate.

Before to formulate models for estimating tag-shedding rates from recaptures, it is important to investigate for the factors that may affect the return rate. For time constraints and availability of the tagging data base still in the validation phase, we limited the explanatory analysis to:

- the size/characteristic of the tag (11 cm CC type vs. 14 cm EE and KK types)
- the position where each double tag is inserted on the fish (Left vs. Right side)
- the tagging cruise (something embedding the skill of the tagging technician, the distance between the tagging area and the fishing ground, etc)
- the double tagging itself (difference in mortality / visibility between simple tagged vs. originally double tagged fish)

Modelling the shedding rate

A simple analysis of the proportion of tags lost over time can be conducted as:

$$P.Obs_t = \frac{n_t^{ds}}{(n_t^{ds} + 2\, n_t^{dd})}$$, Chapman et al, (1965),

with n^{ds} and n^{dd} = numbers of recoveries of originally double tagged fish retaining one (ds) or two tags (dd), respectively, and t time at the middle of the k th time period since release.

For modelling the proportion of tags lost: $P.Fit_t = 1 - Q_t$

with different potential models for the probability Q_t of a tag being retained at time t after release e.g.:

$Q_t = \alpha e^{-(\lambda t)}$, (Hampton, 1997; Adam and Kirkwood, 2001),

$$Q_t = \alpha \left[\beta / (\beta + \lambda t) \right]^{\beta}$$, (Kirkwood, 1981; Hampton and Kirkwood, 1989)

α = type-1 retention probability (i.e., 1 - immediate type_1 shedding rate),

L = continuous type-2 shedding rate,
λ and b = gamma parameters of L allowing a time-varying shedding rate

Under the assumption that all tags not immediately shed have independent and identical probabilities, the probabilities of 2, 1 and no tags being retained at time t after release are, respectively:

$P_t(2) = Q_t^2$;
$P_t(1) = 2\ Q_t\ [1 - Q_t\ ]$;
$P_t(0) = [1 - Q_t]^2$

Since identifiable recaptures consist only of fish retaining either one tag or two tags, conditional on retention of at least one tag, the probability of capturing a fish retaining 2 tags at time t is:

$P_t(2) / (1 - P_t(0))$,

and retaining only one tag at time t is:

$P_t(1) / (1 - P_t(0))$.

Estimates of the model parameters are obtained by minimizing the negative log-likelihood of the data conditional on recapture times:

$LL = - \Sigma \text{ Ln } [P_t(2) / (1 - P_t(0))] - \Sigma \text{ Ln } [P_t(1) / (1 - P_t(0))]$

There are more sophisticated models taking into account differences in reporting rate (i.e., including detection rate) between double and simple tags, differences in continuous tag loss depending on the position/side of the fish where each double tag is inserted, etc (Barrowman and Myers, 1996; Xiao, 1996; Cadigan and Brattey, 2006, among others), or using tag-attrition model (Gaertner et al, 2004).

Results

For analyzing how the length of the tag may affect the return rate we selected 4 cruises where simple tagging and double tagging experiments were conducted simultaneously for both tag types. From figure 2, it can be seen that there is not a clear difference in term of recovery rate per type of length tag (at least for the 3 species). With respect to the position of the tag for the originally double tagged fish (Figure 3), first the proportion of fish returned with only one tag is very low (less than 1% in the majority of the cruises), whatever the species considered. More data and statistical analyzes are required to assess whether the apparent better return rate for the right side location is significant or no. From figure 4, it is showed that the return rate depicts large variation between cruises whatever the species considered. For the cruises which presented a low return rate (e.g., cruise n° 608, 720, 721, 722), after consultation of the logbooks from the purse seine fishery it was concluded that the distance between the area where tagging took place and the seasonal fishing grounds where purse seiners were operating was too large to allow significant recaptures of tagged fish. It must be noted that the return rates per cruise are very similar between simple and double tagging experiments. The very low difference between both suggests that the proportion of tags lost is very low.

Conclusion of the exploratory analysis: Even if additional statistical analysis should be done, there is not strong evidence of difference in return rates between tag types or between the positions of the inserted tag on the fish. In contrast, the tagging experiment (i.e., the cruise) could influence significantly the return rate. In light of this simple comparative analysis, we will assume for modelling the tag shedding that all tags have identical shedding probabilities whatever their length and their position on the fish.

The results concerning the models developed to estimate tag-shedding rates with exact time at liberty from double tagging experiments are showed in tables 1 and 2 and in figure 5. Confidence intervals at 95% (for the constant shedding rate model only) were performed by bootstrapping.

In general, the low values of the tag shedding parameters found in our study are of a similar order to those previously reported by different authors (Hampton, 1997; Adam and Kirkwood, 2001). In contrast, the relative high value (0.22) reported by Adam and Kirkwood (2001) for skipjack in Maldivian waters, and not supported by our data, may reflect in part some emigration away the fishing ground (Table 1). It must be stressed that for skipjack the large value found for β in the shedding time-varying model (Table 2) suggests that the values predicted by this formulation are very close to the predicted values by the constant shedding rate model (as showed in figure 5, where the time-varying model cannot be not distinguished to the constant–rate model). For yellowfin and bigeye, the constant shedding rate model appears as a reasonable compromise but additional data and specifically the integration of longer-term recovery periods should modify the choice of the best tag shedding model. Surprisingly, in spite a "frenetic" behavior during the tagging operation, skipjack does not depict a larger type-1 shedding rate than yellowfin or bigeye (one could expect a larger immediate mortality and/or a larger immediate tag loss for skipjack than for the other two species of tropical tuna which stay relatively quiet during the tagging).

The main conclusion of this preliminary shedding analysis is that the estimated proportion of tags lost was very low for the 3 species of tropical tunas. For instance, the largest shedding rate was observed for yellowfin, which reached around 10% only after 2 years after release (Table 3).

References

Adam, S., Kirkwood, G. P. (2001) Estimating tag-shedding rates for skipjack tuna, *Katsuwonus pelamis,* off the Maldives. *Fish. Bull.* 99 :193-196

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

Barrowman, N. J., and Myers, R. A. (1996) Estimating tag-shedding rates for experiments with multiple tag types. *Biometrics*, 52: 1410-1416.

Chapman, D. G., Fink, B. D. and Bennett, E. B. (1965) A method for estimating the rate of shedding of tags from yellowfin tuna. *Inter-Am. Trop. Tuna Comm. Bull.* 10: 333-352.

Gaertner, D., Hallier, J. P., and Maunder, M. (2004) A tag-attrition model as a means to estimate the efficiency of two types of tags used in tropical tuna fisheries. *Fisheries Research* 69: 171–180

Hampton, J. (1997). Estimation of tag reporting and tag-shedding rates in a large-scale tuna tagging experiment in the western tropical Pacific Ocean. *Fish. Bull.* 95: 68–79.

Hampton, J., and Kirkwood, G. P. (1990) Tag shedding by southern bluefin tuna *Thunnus maccoyii*. *Fish. Bull.* 88: 313–321.

Kirkwood, G. P. (1981) Generalised models for the estimation of rates of tag shedding by southern bluefin tuna. *Thunnus maccoyii*. *J. Cons. Int. Explor. Mer* 39: 256-260.

Wetherall, J. A. (1982) Analysis of double tagging experiments. *Fish. Bull.* 80(4): 687-701

Xiao, Y. (1996). A general model for estimating tag-specific shedding rates and tag interactions from exact or pooled times at liberty for a double tagging experiment. *Can. J. Fish. Aquat. Sci.* 53(8): 1852–1861.

Table 1. Parameter estimates with bootstrapped confidence intervals (B.C.I.) for the constant shedding rate model (i.e., the probability of retention $Q(t) = \alpha \exp^{(-\lambda t)}$) from double tagging experiments for the 3 main tuna species in the Indian Ocean.

Species	α	95% B.C.I.	λ (per year)	95% B.C.I.	
SKJ	0.981	(0.972 - 0.990)	0.020	(0.003 – 0.037)	present study
	0.97	(0.94 - 1.00)	0.22	(0.09- 0.35)	Adam-Kirkwood 2001
	0.965		0.086		Hampton 1997
YFT	0.973	(0.962 - 0.983)	0.039	(0.019-0.057)	present study
	0.934		0.018		Hampton 1997
BET	0.988	(0.982 - 1.000)	0.011	(0.000- 0.031)	present study
	0.953		<0.001		Hampton 1997

Table 2. Parameter estimates for the time varying shedding rate model (i.e., the probability of retention $Q(t) = \alpha [\beta / (\beta + \lambda t)]^{\beta}$ from double tagging experiments for the 3 main tuna species in the Indian Ocean.

Species	α	λ (per year)	β	
SKJ	0.981	0.020	4070.824	present study
YFT	0.976	0.053	0.100	present study
BET	1.000	0.210	0.007	present study

Table 3. Estimated proportion of tags lost, immediately after release and after one and two years at liberty, respectively, from the constant shedding rate model for the 3 main tuna species in the Indian Ocean.

	Years		
Species	0	1	2
BET	0,012	0,023	0,033
SKJ	0,019	0,038	0,057
YFT	0,027	0,064	0,099

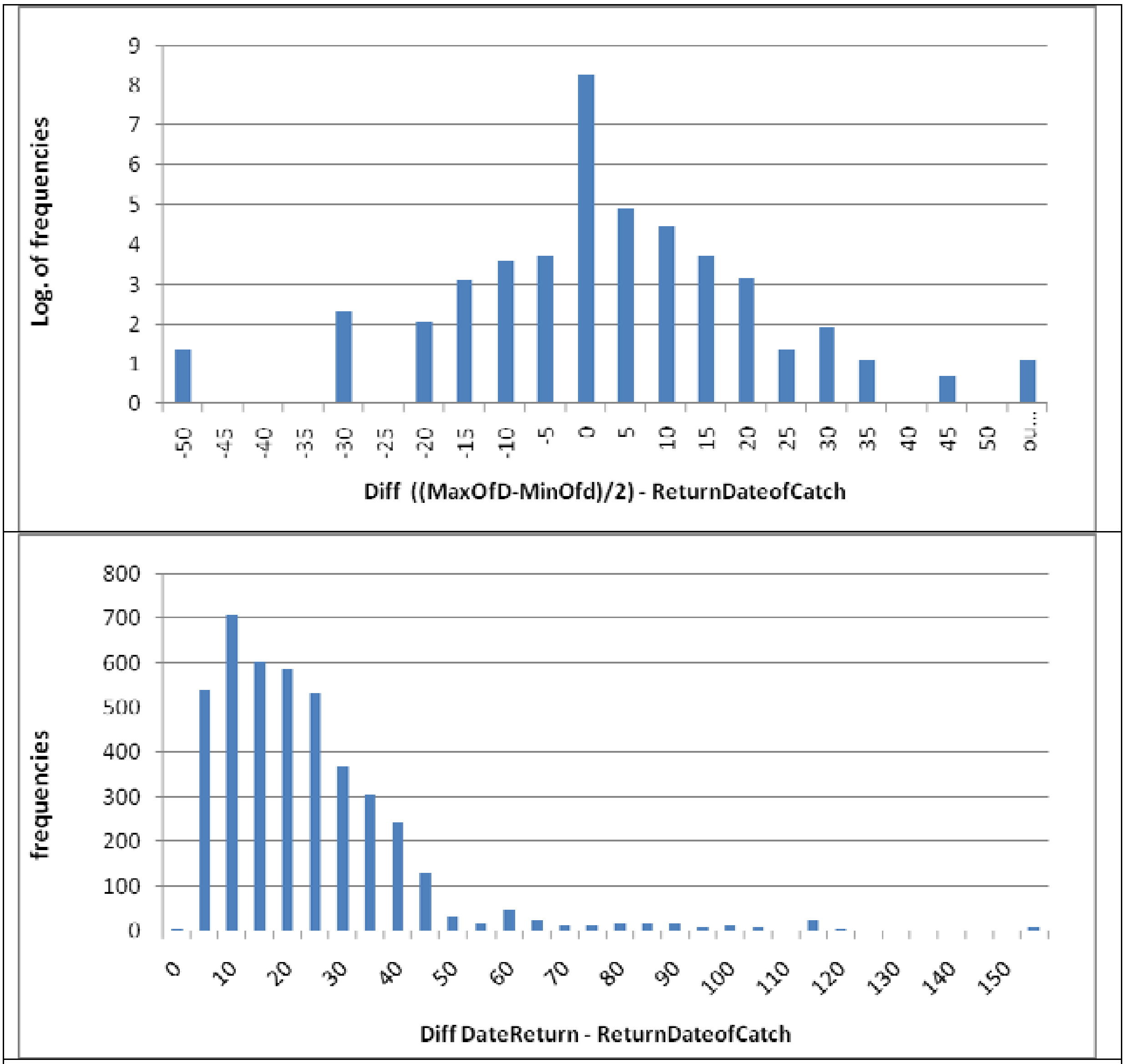

Figure 1. Observed difference between the true date of recapture (i.e., the ReturnDateofCatch) and different dates of substitution. Upper part represents the case when substitution is based on the average of the dates for the sets suspected to have caught the tagged fish (for convenience, frequencies are presented in logarithmic scale). Lower part represents the case when there is no other way than to use the date at which the tag was reported to scientist.

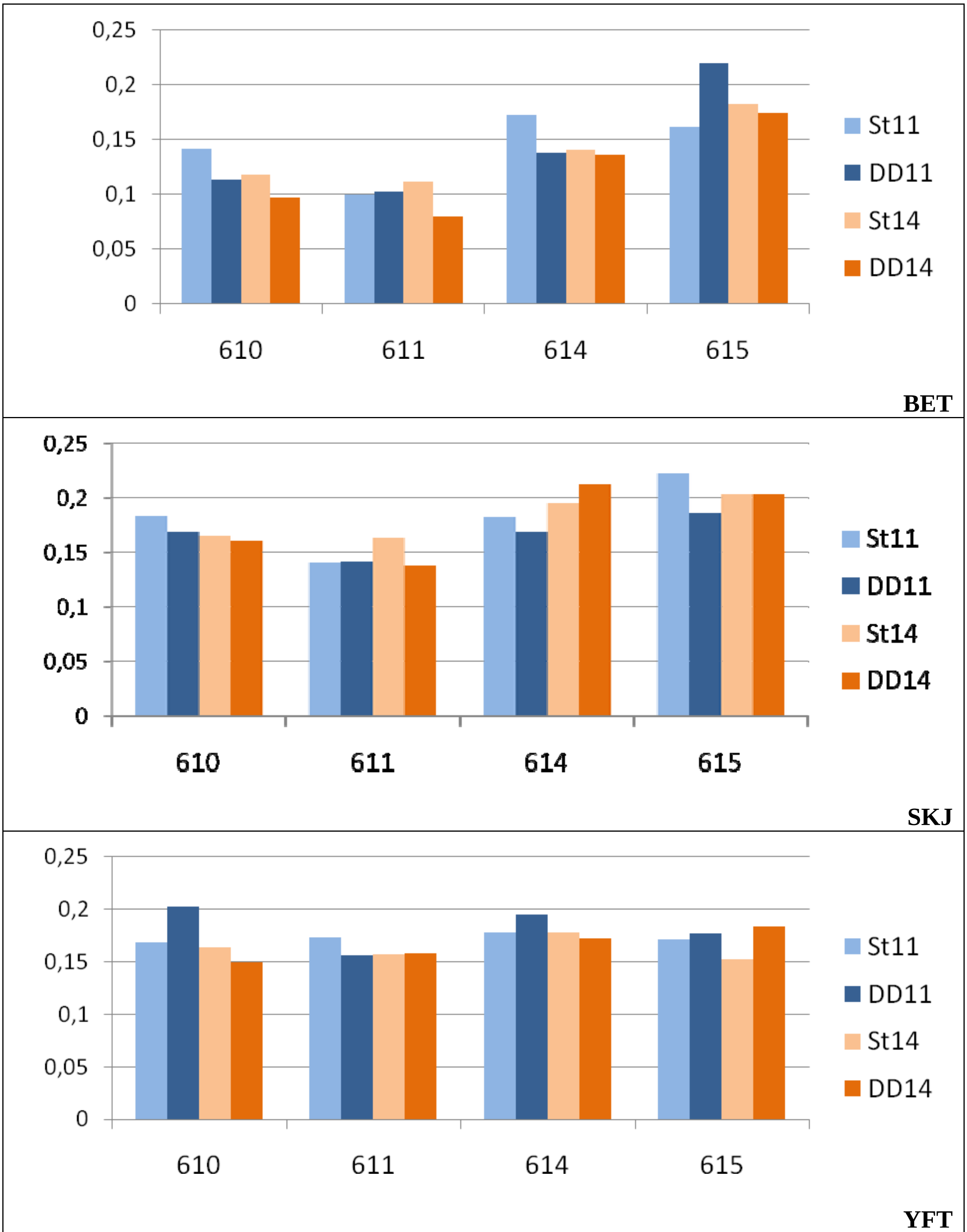

Figure 2. Comparison of the return rates per tagging cruise between 11 cm and 14 cm tag types for the 3 main species of tropical tunas in the Indian Ocean: Bigeye (upper part), Skipjack (median part) and Yellowfin (lower part).

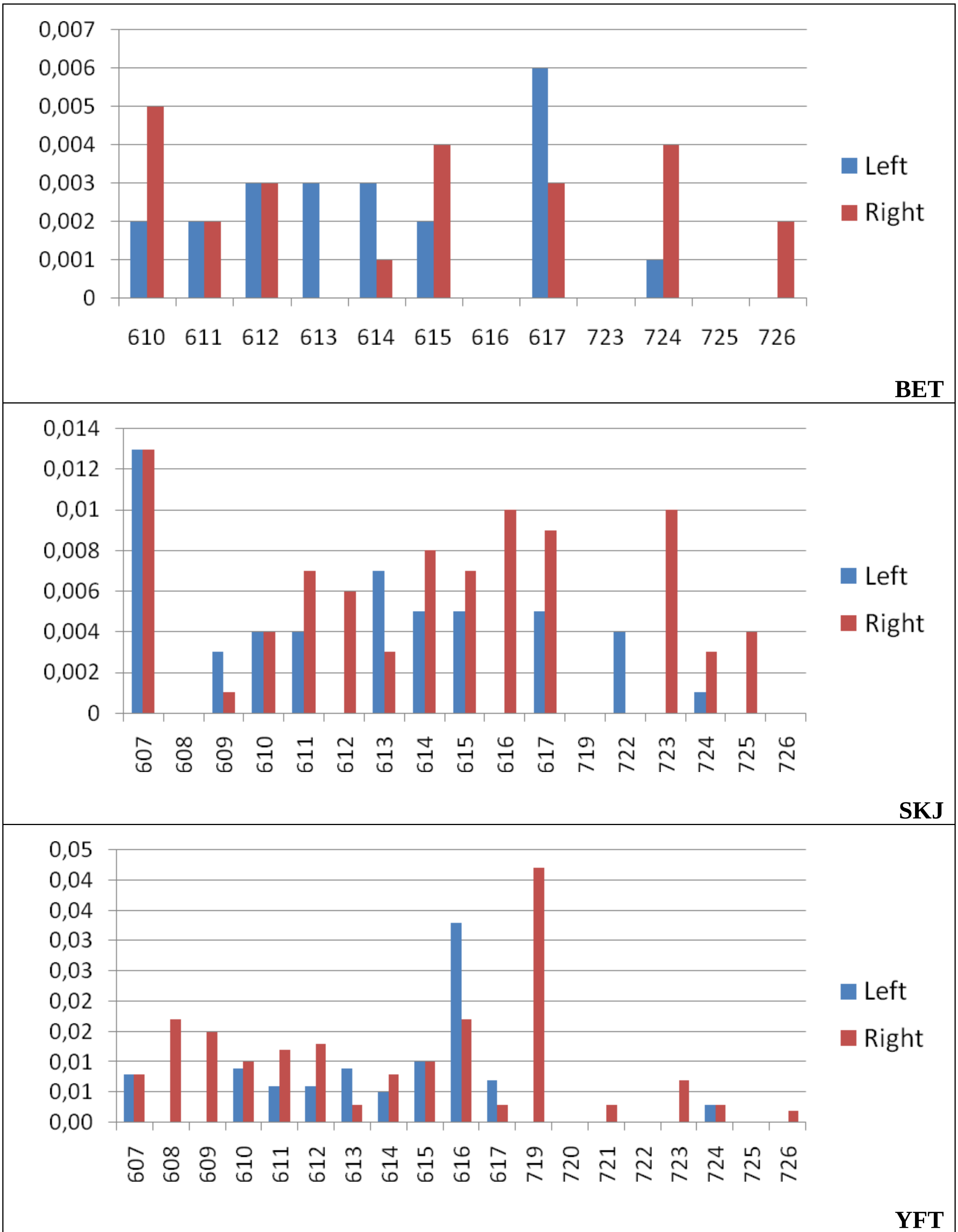

Figure 3. Comparison of the return rates per tagging cruise between the position of the tag insertion for the fish originally double tagged for the 3 main species of tropical tunas in the Indian Ocean: Bigeye (upper part), Skipjack (median part) and Yellowfin (lower part).

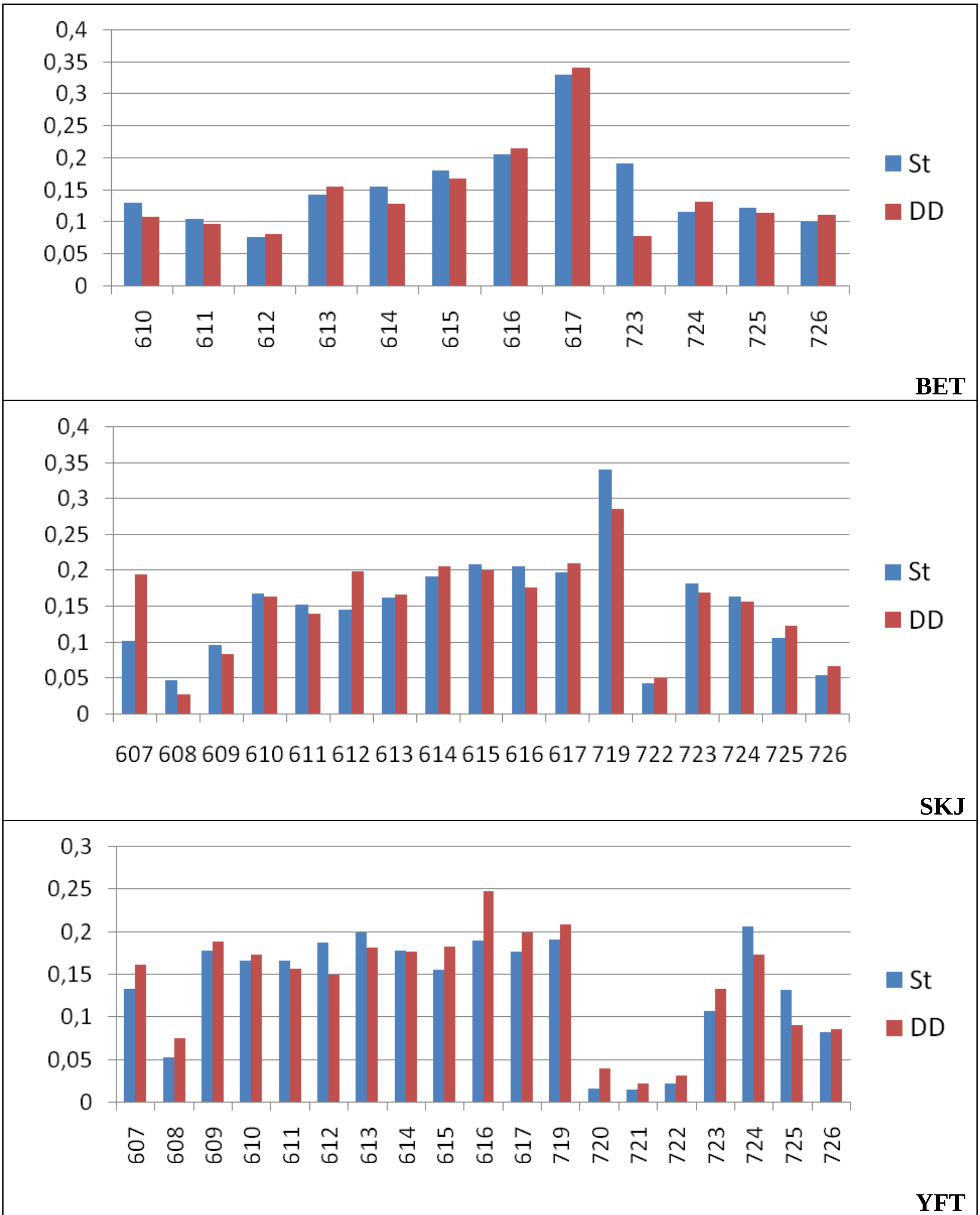

Figure 4. Comparison of the return rates per tagging cruise between the position of the tag insertion for the fish originally double tagged for the 3 main species of tropical tunas in the Indian Ocean: Bigeye (upper part), Skipjack (median part) and Yellowfin (lower part).

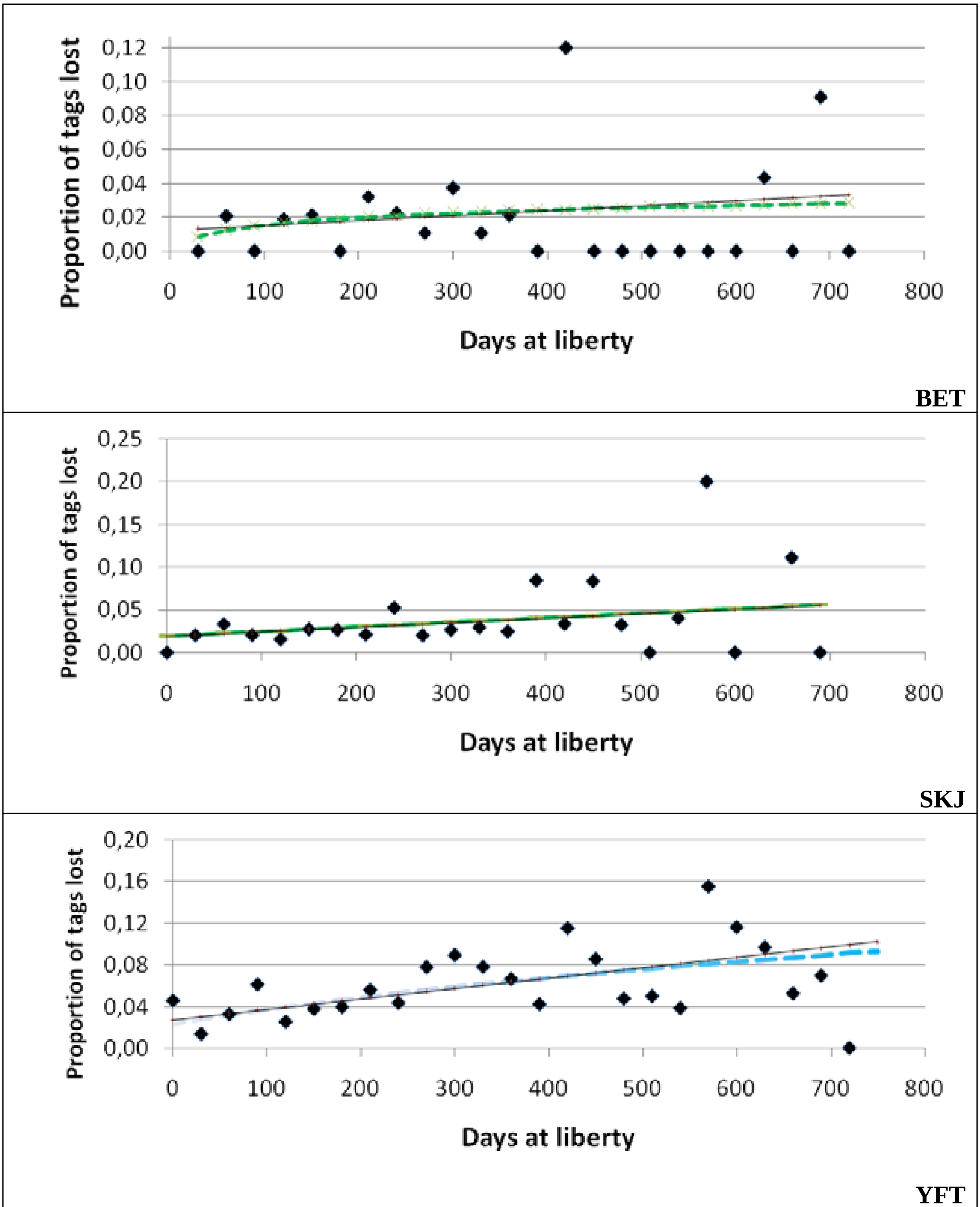

Figure 5. Proportion of tags lost per days at sea for the fish originally double tagged for the 3 main species of tropical tunas in the Indian Ocean: Bigeye (upper part), Skipjack (median part) and Yellowfin (lower part). Solid line = constant type-2 shedding rate model; broken line = time-varying type-2 model. Models were fitted with exact days at liberty but observed shedding rates are represented by time periods of 30 days.