Tag-Shedding by Tropical Tunas in the Indian Ocean and other factors affecting the shedding rate

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INDIAN OCEAN TUNA TAGGING SYMPOSIUM
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- A) statistical analysis of a tagger effect and other explanatory variables that were hypothesized a priori to influence tag loss,

- B) comparison between a constant-rate shedding model and a time-varying shedding model

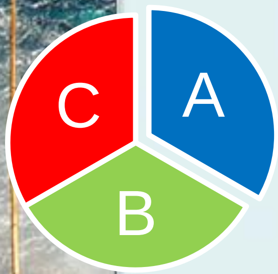
- C) attempt to account directly for a tagger effect on parameter estimates in the conventional tag-shedding approach

Data set:

Double tagging experiments conducted on board baitboat since january 15th 2006 (i.e., RTTP cruise number >= 607)

Only fish with a good condition reliability at release (i.e., “good”, coded as 1) and clearly identified as the same species at release and at recovery

This reduced to a total of 26,899 double-tagged tuna released, 4,555 recovered so far including 329 having lost one of their tags.

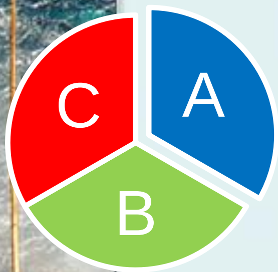


Statistical analysis of a tagger effect and other explanatory variables that were hypothesized *a priori* to influence tag loss,

Response variable = proportion of double tagged fish recovered with only one tag

Candidate explanatory variables:
species *S* (yellowfin, bigeye, skipjack),
tagger identification *T*,
cruise identification *C*,
experience *E*, gained by each tagger over the tagging program period (expressed as the cumulative total number of simple and double tags previously released by tagger *T* at the beginning of the cruise *C*).

To account for variability in proportions of fish recovered and to avoid bias in tag-shedding estimates due to a potential tagger effect when data are pooled by tagger, recoveries were pooled by batch (i.e., at a tagger and cruise level), as suggested by Hearn et. al. (1991), However, to avoid extreme variability in shedding rate due low sample size, batches with less than 10 recoveries were omitted



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The Beta-binomial model

Owing to the clustered structure of the data it makes sense to assume that the rate of tag loss *y* has **extra-binomial variation**. One way to account for **over-dispersion** in proportions is to use a more general probability model than the binomial such as the beta-binomial.

After including the mean μ and the precision parameter Φ in the conventional form, the beta density can be expressed as:

$$f(y; \mu, \emptyset) = \frac{\Gamma(\emptyset)}{\Gamma(\mu \emptyset)\, \Gamma((1-\mu)\emptyset)} y^{\mu \emptyset - 1} (1-y)^{(1-\mu)\emptyset - 1} \qquad 0 < y < 1$$

with $0 < \mu < 1$ and $\Phi > 0$ (Ferrari and Cribari-Neto, 2004). A beta-distributed variable *y* has mean $E(y) = \mu$ and variance $VAR(y) = \mu(1-\mu)/(1+\emptyset)$.

Let $y_1, \ldots, y_n$ be a random sample such that $y_i \sim B(\mu_i, \Phi)$, i = 1,…,n.
The beta regression model is defined as : $g(\mu_i) = \beta_1 x_{i1} + \ldots + \beta_k x_{ik}$, where β is a vector of unknown coefficient and x the vector of the k explanatory variables.

In addition if the precision parameter is assumed to be not constant for all observations (i.e., $y_i \sim B(\mu_i, \emptyset_i)$) it can be modeled in a similar fashion as the mean parameter, that is to say: $g(\emptyset_i) = \gamma_1 z_{i1} + \ldots + \gamma_k z_{ik}$.

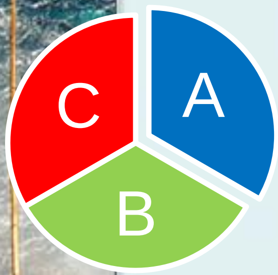
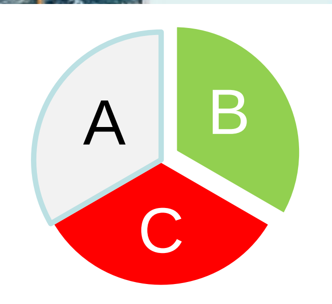


Table 1. Model selection for determining shedding rates from double tagged tunas, with: K = number of parameters, BIC = Bayesian Information Criterion, W_i = Akaike's information criterion weight. Models have been ranked from best to worst according to the Akaike's information criterion weights. Explanatory variables used in the candidate beta-binomial models were: S = Species, T = Tagger, C = Cruise, E = Experience gained by the tagger over the period considered.

Beta-binomial Model				
Mean	Precision	K	BIC_i	W_i
S		4	-565.31	0.992
S	S	6	-555.54	0.001
S	C	17	-522.06	0.000
S + T		22	-496.55	0.000
S	T	22	-494.93	0.000
S + T + E		23	-491.56	0.000
S + T	S	24	-488.80	0.000
S + T	C	35	-481.95	0.000
S + T	T	40	-480.77	0.000
T		20	-474.97	0.000
S + T	T + C	53	-466.29	0.000
S + T + C		35	-447.61	0.000
S	C + T	35	-445.85	0.000
S + T + C + E		36	-443.05	0.000

$BIC = -2 \log \left[L(\hat{\beta}, \hat{\gamma} / data) \right] + K \log(n)$ where *n* = number of observations, *K* = number of parameters of the model, $L(\hat{\beta}, \hat{\gamma} / data)$ = value of the maximized log-likelihood over the unknown parameters, given the data and the model. $W_i = \left[\exp\left(\frac{-\Delta BIC i}{2} \right) \right] / \sum_i \left[\exp\left(\frac{-\Delta BIC i}{2} \right) \right]$
where, $\Delta BIC i = BIC_i - \min BIC$

Tagger effect not supported by the data



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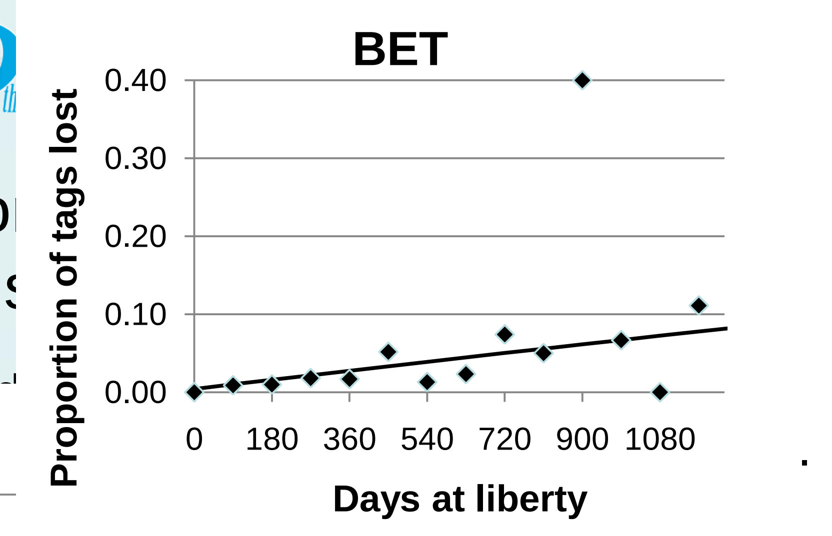
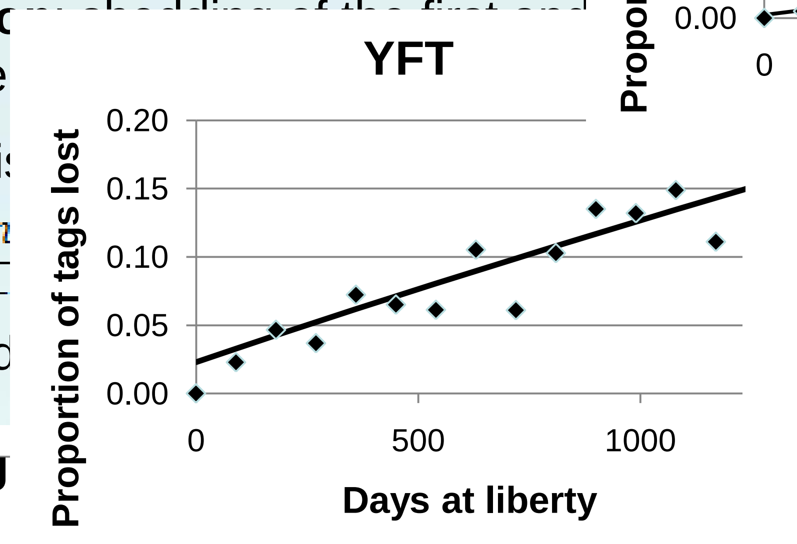
Comparison between a co
model and a time-varying s



Main assumptio

at the same rate



A simple analysis

recoveries of originally

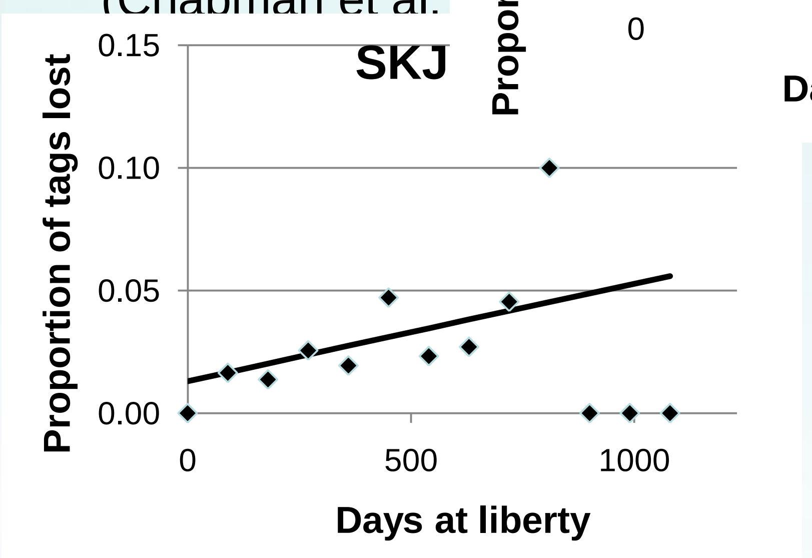
ne (ds) or two tags (dd),

$P.Obs_t = \frac{n}{(n_t^{ds} + }$

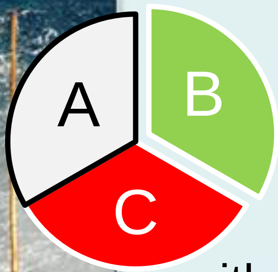
respectively, and

eriod since release

(Chapman et al.



but due to the low sample size for some classes of time at liberty the proportion of tags lost may be biased. It seems more appropriate to model this process with **individual time at liberty**.



Thus, for modelling the proportion of tags lost: $P.Fit_t = 1 - Q_t$
with **individual time at liberty,** different models have been proposed to express the probability Q_t of a tag being retained at time t after release e.g.:

model A: **a constant-rate shedding model**

$$Q_t = \propto \ e^{-(L\ t)}$$

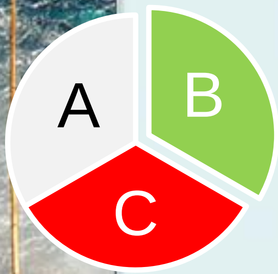
(Hampton, 1997; Adam and Kirkwood, 2001),

model B: **a time-varying shedding model**

$$Q_t = \propto \left[\beta / (\beta + \lambda\ t) \right]^{\beta}$$

(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 β = 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:

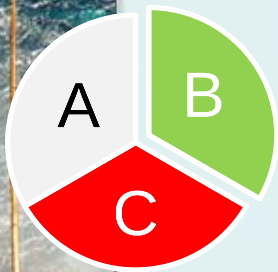
$$P_t(2) = Q_t^2 \qquad P_t(1) = 2\,Q_t\,[1 - Q_t] \qquad P_t(0) = [1 - Q_t]^2$$

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:

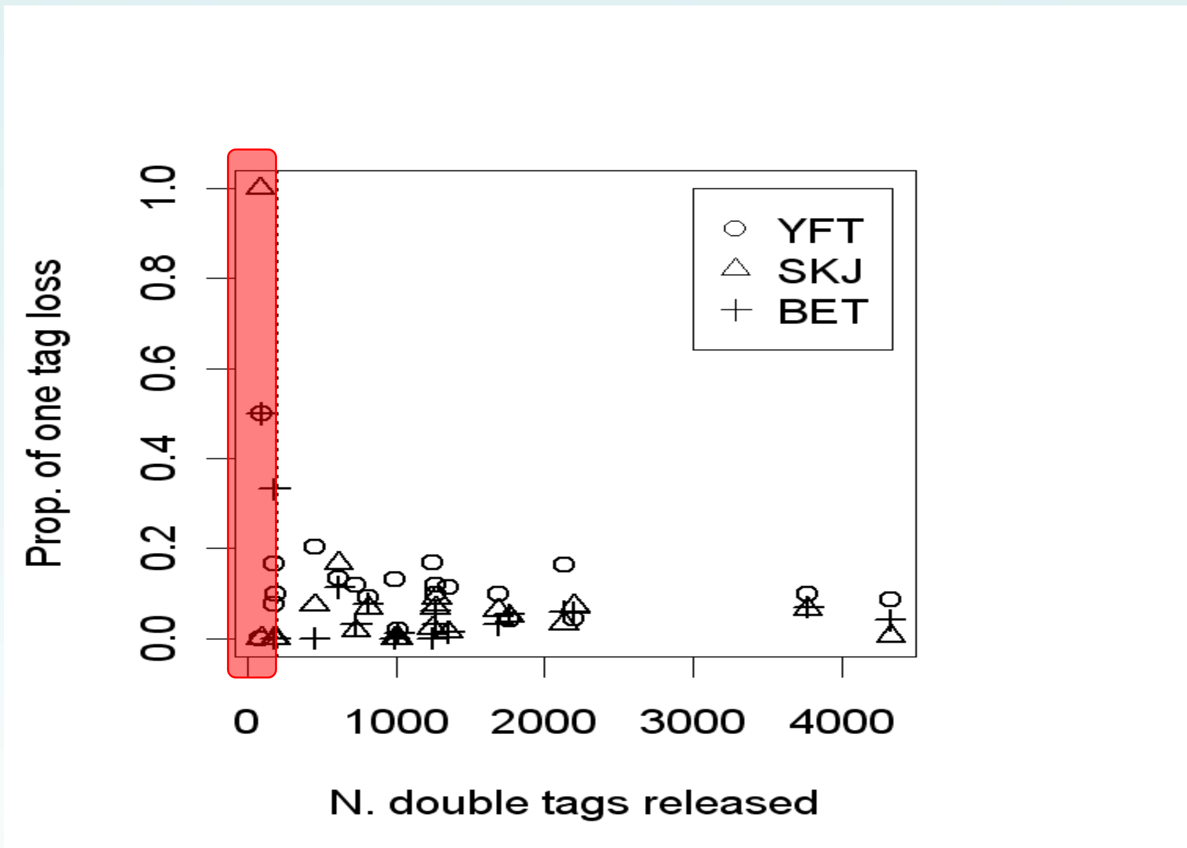
$P_t(2) / (1 - P_t(0))$ and retaining only one tag at time t is: $P_t(1) / (1 - P_t(0))$

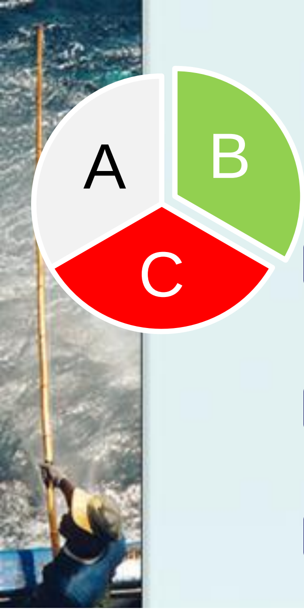
Estimates of the model parameters are obtained by minimizing the negative log-likelihood of the data conditional on recapture times:

$$LL = -\sum Ln\left[P_t(2) / (1 - P_t(0))\right] - \sum Ln\left[P_t(1) / (1 - P_t(0))\right]$$

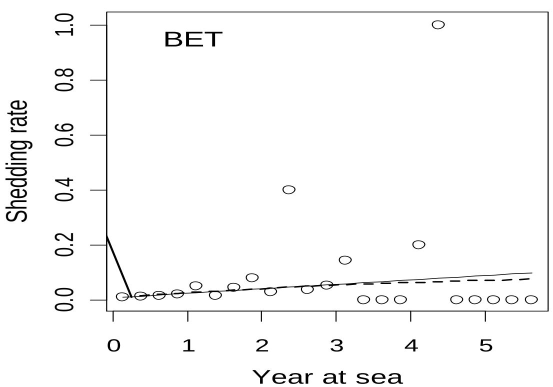


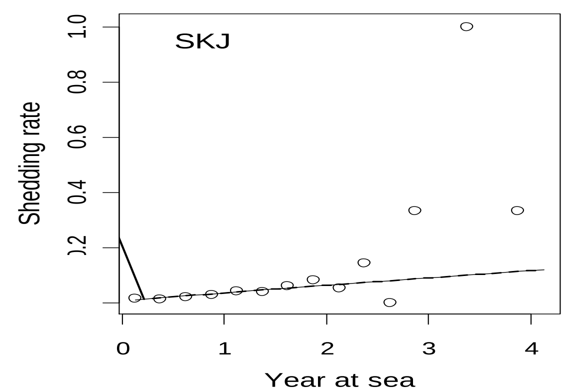
Even if a tagger effect was not evidenced, taggers with less than 200 double tags released depicted larger variability in terms of one tag loss rate than experienced taggers, consequently an arbitrary threshold of 200 releases by tagger was chosen to avoid the presence of unusual values

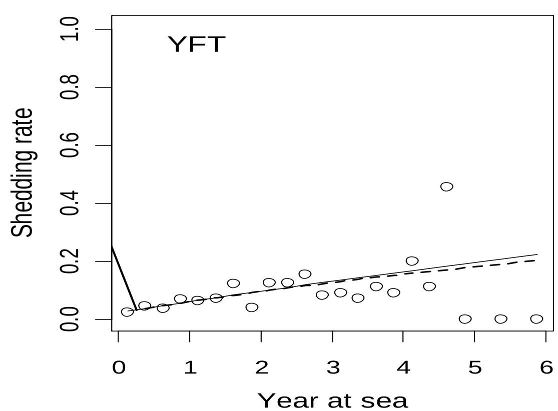


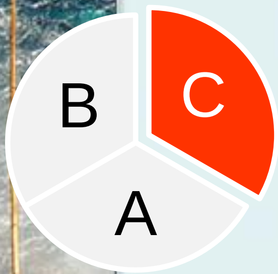


Species	Model	α	L (per year)	β	Ndd	Nds	BIC_i	W_i
SKJ	constant	0.993	0.029		1374	65	520.44	0.974
	time varying	0.993	0.029	142569.4			527.72	0.026
YFT	constant	0.977	0.039		1717	204	1264.23	0.977
	time varying	0.978	0.042	0.526			1271.71	0.023
BET	constant	0.993	0.017		1079	48	396.37	0.958
	time varying	0.995	0.025	0.063			402.61	0.042









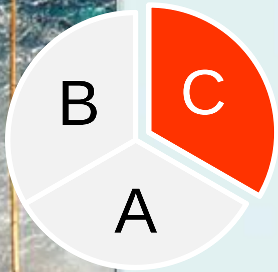
Attempt to account directly for a tagger effect on parameter estimates in the conventional tag-shedding approach

To reinforce the analysis of the potential tagger bias on the proportion of one-tag recoveries among the double tagged fish with a beta-binomial model we included directly this assumption in the shedding rate model in the same way as conducted on a cruise effect in a previous study (Gaertner and Hallier, 2009).

model A0 $Q_t = \propto \; e^{-(L\ t)}$ base case model;

model A1 $Q_t = \propto_i \; e^{-(L\ t)}$ type-1 shedding rate (i.e., α) varies by tagger *i*;

model A2 $Q_t = \propto \; e^{-(L_i\ t)}$ type-2 shedding rate (i.e., L) varies by tagger *i*.



Species	Model	K	Nll	QAICc	Wi
	A0	2	252.950	520.443	1.000
SKJ	A1	17	244.401	612.421	0.000
	A2	17	239.217	602.053	0.000
	A0	2	624.553	1264.227	1.000
YFT	A1	17	611.172	1350.874	0.000
	A2	17	609.209	1346.948	0.000
	A0	2	191.155	396.367	1.000
BET	A1	17	185.946	491.356	0.000
	A2	17	183.631	486.726	0.000

Same conclusion, as for the analysis conducted on the potential difference in total tag loss between taggers with a Beta-binomial model, there were no evidence of a tagger-varying type-1 shedding and tagger-varying type-2 shedding effects

C A B

General conclusions

Table 4. Parameter estimates with bootstrapped confidence intervals (95% B.C.I.) for the constant shedding rate model (i.e., the probability of retention $Q(t) = \alpha \exp^{(-L t)}$) from double tagging experiments for the 3 main tuna species in the Indian Ocean.

Species	α	95% B.C.I.	*L* (per year)	95% B.C.I.	
SKJ	0.993	(0.987 - 0.999)	0.029	(0.018 – 0.040)	present study
	0.97	(0.94 - 1.00)	0.22	(0.09- 0.35)	Adam-Kirkwood 2001
	0.965		0.086		Hampton 1997
YFT	0.977	(0.967 - 0.986)	0.039	(0.027-0.050)	present study
	0.934		0.018		Hampton 1997
BET	0.993	(0.985 – 1.000)	0.017	(0.008- 0.025)	present study
	0.953		<0.001		Hampton 1997

Results in agreement with other studies; tag shedding is relatively low for tropical tunas

Table 5. Estimated proportions of tags lost, immediately after release and until 5 years at liberty, respectively, from the constant shedding rate model for the 3 main tuna species in the Indian Ocean. Approximate C.I. were calculated from 95% lower and upper parameter estimates of the constant shedding rate model.

	Years					
Species	0	1	2	3	4	5
SKJ	0.007	0.035	0.063	0.090	0.116	0.141
	(0.001-0.013)	(0.031-0.040)	(0.048-0.078)	(0.065-0.114)	(0.082-0.149)	(0.098-0.182)
YFT	0.023	0.060	0.096	0.131	0.164	0.196
	(0.014-0.033)	(0.059-0.062)	(0.084-0.108)	(0.108-0.151)	(0.132-0.193)	(0.155-0.232)
BET	0.007	0.024	0.040	0.056	0.072	0.088
	(0.000-0/015)	(0.023-0.025)	(0.031-0.049)	(0.038-0.072)	(0.046-0.095)	(0.054-0.118)

Larger values of shedding rate observed for YFT, but only 20% of tag loss after 5 years at sea

Thanks for your attention