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EFFECTS OF RELEASE FACTORS AFFECTING THE RECOVERY RATES OF TAGGED TUNAS: APPLICATION TO BIGEYE TUNA

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SUMMARY

The tagging data base compiled since the 1960s by the secretariat of ICCAT was used to assess the effects of several release factors on the recovery rate of bigeye tuna (Thunnus obesus). The release factors considered were the length of the fish, the latitude, the longitude, the gear used during the tagging operation, the kind of tag used, the year and the month as well as the interactions between the length and the tag type and the length and the year. It was showed that all of these explanatory variables influenced significantly the probability of return of the fish and were used within a GLM framework to predict the probability of recapture of the fish. Results from this model reinforce previous findings concerning the lower efficiency of Betyp tag compared with Spaghetti tag but also highlighted the fact that this detrimental effect concerns only fish lower than 80 cm (FL). Other aspects related to the presence of interactions and the difficulty to discern from inspection of the coefficients how some factors combine to influence the probability of recapture are also discussed.

RÉSUMÉ

*La base de données de marquage compilée par le Secrétariat de l'ICCAT depuis les années 1960 a été utilisée pour évaluer les effets de divers facteurs de marquage sur le taux de recapture de thon obèse (*Thunnus obesus*). Les facteurs considérés étaient la taille du poisson, la latitude, la longitude, l'engin employé pendant l'opération de marquage, le type de marque utilisé, l'année et le mois ainsi que les interactions entre la taille et le type de marque et la taille et l'année. Il s'est avéré que toutes ces variables explicatives avaient une forte influence sur la probabilité de recapture des poissons. Elles ont été incluses dans un Modèle Linéaire Généralisé (GLM) afin de prévoir la probabilité de recapture des poissons. Les résultats de ce modèle renforcent les conclusions antérieures sur la faible efficacité des marques BETYP par rapport aux marques spaghetti mais soulignent également que cela n'affecte que les poissons de moins de 80 cm (FL). Ce document aborde aussi d'autres aspects liés à la présence des interactions et à la difficulté d'identifier, d'après l'inspection des coefficients, dans quelle mesure certains facteurs se combinent pour influencer la probabilité de recapture.*

RESUMEN

Se utilizó la base de datos sobre marcado recopilados desde los años sesenta en la Secretaría de ICCAT para evaluar los efectos de varios factores de marcado en la tasa de recuperación de patudo (Thunnus obesus). *Los factores de marcado considerados fueron la talla del pez, la latitud, la longitud, el arte utilizado durante la operación de marcado, el tipo de marca utilizado, el año y el mes, así como las interacciones entre la talla y el tipo de marca y la talla y el año. Se vio que todas estas variables explicativas influían considerablemente en la probabilidad de recuperación del pez y se aplicó un marco GLM para predecir la probabilidad de recuperación de los ejemplares. Los resultados de este modelo confirmaron los hallazgos anteriores sobre la escasa eficacia de la marca BETYP en comparación con la marca espagueti, pero también pusieron de relieve el hecho de que este efecto negativo sólo afecta a los ejemplares de menos de 80 cm (FL). También se debaten en el documento otros aspectos relacionados con la presencia de interacciones y la dificultad de discernir, a partir de la inspección de coeficientes, el modo en que algunos factores se combinan para influir en la probabilidad de recuperación.*

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1. Introduction

Tag-recovery studies (mainly with external spaghetti tags) have always been component to collect indispensable information on stock structure, growth rate, gear selectivity, migrations, survival/mortality, etc. for stock assessment studies (Jones 1976, McFarlane *et al.* 1990). However the efficiency of such studies is dependent on the recovery rates which are strongly related to release factors during the tagging surveys themselves (Wise 1963; Fowler and Stobo 1999).

Since the beginning of the 1960s, several tagging activities were conducted in the tropical Atlantic Ocean by different countries, with different fishing practices (e.g. gear, location, season, type of tags, etc). The tagging data base compiled by the ICCAT Secretariat contains a total of 17804 records for yellowfin (*Thunnus albacares*), 11167 for bigeye (*Thunnus obesus*) and 35965 for skipjack (*Katsuwonus pelamis*). Although suggestions of error checking rules have been made in order to improve the quality of the information collected (Gaertner *et al.* 2007), the ICCAT tagging database for tropical tunas is still under revision. Since more attention has been paid to bigeye tuna in the framework of the Bigeye Year Program, the tagging data used in this paper have been restricted to this species. Consequently, this study must be considered as a preliminary attempt to check for release factors influencing the return rates of tropical tunas. We hope, nevertheless, that this type of study will be useful in the design of tagging protocols and the analysis of tagging data.

2. Materials and methods

2.1 Data

Features of the release tagging operation dealt with in this preliminary study comprise tag type, fish length (FL in cm), latitude of release, longitude of release, year of release, month of release and gear of release **(Table 1)**.

Tag type concerns 3 kinds of tags: the yellow "spaghetti" tag (the conventional tag widely used for tagging of tuna), a red "spaghetti" tag (characterizing individuals which were injected with oxytetracyclin antibiotic –OTC- to validate the growth ring deposit in growth studies) and another type of tag commonly used by the sport fishermen, which was used during the "Bigeye Year Program" (BETYP). While "spaghetti" tags (also termed "T-bar" tags) use a nylon filament with a T-shaped tip to anchor it in the muscle of the fish, Betyp tags have a big head with one hook on each side which gives a firmer hold of the tag into the fish. However, the lower efficiency of the Betyp tag type, specifically on the recapture rate of bigeye tuna (*Thunnus obesus*), was showed in previous studies (Hallier and Gaertner 2002; Gaertner and Hallier 2004).

With respect to the month of release, we assumed for the sake of simplicity that the months in the southern hemisphere have the same influence on the return rate as their equivalent with a lag of 6 months in the northern hemisphere (i.e., July for southern latitudes is assumed to be equivalent to January for northern latitudes). We are aware about this simplification since latitudinal patterns of environmental factors are not automatically symmetric in both tropical areas, and seasonality in equatorial areas may be less pronounced (or structured differently). In the lack of further information on this topic, it seems reasonable to assume that this transformation is more realistic than mixing the original month values between both hemispheres.

2.2 Methods

Application of linear statistical models by accommodating responses variables with non-normal conditional distribution is known as generalized linear models (GLM). Since the response variable is binary: recapture (1) or not (0), we use a binomial GLM to model the effects of the candidate release factors on the probability of return.

To account for the parsimony of the model, that is to say to reach a trade-off between the extremes of under fitting the data (too little structure which means large bias) and over fitting the data (too many parameters, hence large variance) we use the conventional Akaike Information Criterion (AIC). Once an adequate model is selected, the neighbouring nested models are checked with the help of the likelihood ratio test to detect whether important factors (including interactions) are necessary. Regression diagnostics were used to judge the goodness of-fit of the model. They included an overall measure of fit assessed by the "pseudo R^2" and conventional diagnostic plots to identify outliers and influential observations (Venables and Ripley, 2002; p. 151-155, Fox, 2002; p. 225-233).

3. Results

Even if technically all types of interactions can be analyzed, it makes sense to limit the model selection procedure only to the interactions of interest. For this reason, we investigate for the significance of the interactions between the length at release (*rLi*) and (1) the year at release (*Year*) and, (2) the kind of tag (*Tagtype*).

Analyses of deviance are depicted in **Table 2**. Adding the interaction *rLi:Year* is seen to result in a very significant decrease in the deviance (236.52), which can be evaluated with a aid of a chi-square statistic with a single degree of freedom. Adding the interaction *rLi:Tagtype* to the model results in a further decrease in deviance of 29.66 (for 2 df), which is again significant. Consequently, both interactions contribute to the probability of recapture of tagged bigeye tuna to the release factors considered.

The final model can be expressed as:

Log[p/(1-p)] = intercept+ rLi + rLat + rLon + Year + Month + rGear+ Tagtype + rLi:Year + rLi:Tagtype
with *p* = probability of recapture.

An example of diagnostic plot corresponding to this model is presented in **Figure 1**. As here residuals are not expected to be normal, the confidence envelope was built with pseudo-residuals generated from a binomial distribution. The majority of observed residuals lie within the calculated envelope and there is no indication of any outlier giving cause for concern. The estimated regression coefficients for the model are shown in **Table** 3. The signs of the main effects for *rLi* and *Year* imply that increasing these factors increases the odds of recapture (i.e. *p/(1-p)*).

It is difficult to discern from inspection of the coefficients how *rLi*, *Year* and *Tagtype* combine to influence the probability of recapture. Although interpreting the influence of explanatory variables in presence of interactions must be done with caution, it appears that compared with the "spaghetti" tag (here, the reference level), BETYP tag and OTC tags are less efficient. The presence of a positive sign for the coefficients associated with each interaction indicates that this negative effect is less pronounced when length at release increases. To illustrate this point we allow length at release and tagtype to vary over their range or levels and we set the other predictors (i.e., latitude, longitude, year, month, and gear) to constant values.

Apparently length at release has quite a different relationship to the probability of return for conventional "Spaghetti" tags and BETYP tags. A bigeye smaller than 80 cm (FL) is more likely to be recaptured when tagged with a paghetti tag than with a BETYP tag, while there is no evidence of such difference for larger fish **(Figure 2)**. For individuals tagged with OTC injection, the red spaghetti tag would increase the probability of recapture, specifically for individuals between 50 and 100 cm (we can speculate that the probability of detection is related with the colour of the tag)

In the same way, the probability of recapture appears to vary according to the size of the fish **(Figure 3)**. For small bigeye (30 cm FL), the low recovery rate depicts an increasing trend over the years, whereas the opposite is seen for intermediate (70 cm) and large fish (120 cm). Assuming a low recovery rate for small bigeye seems plausible and may have several explanations: high natural mortality (including additional mortality due to tagging), tag shedding, etc. In contrast, the decreasing pattern and the very high fitted probability observed for the other size class must be considered with caution and need further study before to drawn a conclusion.

The higher recovery rate for bigeye tagged on board baitboat (compared to the negative values associated with the levels LL, PS and UN) appears intuitively reasonable. Surprisingly the SP coefficient (i.e. gathering hand line and rod and reel) was also negative (may be due to some interactions not taken into account in the present model).

4. Discussion and conclusion

Since the revision procedure of the ICCAT tagging database is not finished yet, this study must be considered as preliminary. We are aware about the needs to perform additional research to define how to categorize more accurately some factors as well as the usefulness of non-linear relationships between the predictors and the response variable. However, and even with these limitations, results are in agreement with previous studies or do not contradict previous knowledge about this topic. For instance this study reinforces the analyses made by

Hallier and Gaertner (2002) and Gaertner and Hallier (2004) who concluded to the lower efficiency of the BETYP tag type, specifically for the recapture rate of bigeye tuna. In addition, we show that the detrimental effect caused by the BETYP tag affects mainly fish smaller than 80 cm (FL).

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Table 1. Candidate release factors used to fit the probability of recapture.

Variable	*Description*	*Remark*
Y	Recapture	Yes (1), No (0)
rLi	Length at release (cm)	20 – 180 cm
rLon	Longitude	91.46 W–11.00 E
rLat	Latitude	28.81 S–50.65 N
Year	Year	1962–2003
Month	Month (with Month + 6 for Latitude S)	1–12 (factor)
rGear	Gear at release	BB, LL, PS, TR, SP (RR+HD), UN
Tag type	Type of tags	Spaghetti, Betyp, OTC,

Table 2. Generalized linear models and associated statistics for describing the probability of recapture for bigeye as a function of the intercept, the length at release (*rLi*), the location at release (*rLat* and *rLon*), the year and the month at release (*Year* and *Month*), the gear at release (*rGear*), the type of tags (*Tag type*) and several interactions. Models have been ranked from best to worst according to the Akaike critérion.

Model y =f (Release factors)	*Res. dev.*	*d.f*	*AIC*	*Pseudo-R^2*
y ~ rLi + rLat + rLon + Year + Month + rGear + Tagtype + rLi:Year + rLi:Tagtype	8280.251	10212	8332.25	0.321
y ~ rLi + rLat + rLon + Year + Month + rGear + Tagtype + rLi:Year	8309.910	10214	8357.91	0.319
y ~ rLi + rLat +rLon + Year + Month + rGear +Tagtype + rLi:Tagtype	8516.774	10213	8566.77	0.302

Table 3. Release parameter estimates from the best GLM used to predict the recovery rate of tagged igeye tuna in the Atlantic Ocean.

Coefficients	*Value*	*Std. error*	*t value*
Intercept	-663.957	64.488	-10.296
rLi	16.521	1.225	13.485
rLat	-0.139	0.008	-16.631
rLon	-0.165	0.008	-20.502
Year	0.331	0.032	10.233
February	0.852	0.367	2.338
March	-2.284	0.401	-5.689
April	-0.722	0.570	-1.267
May	-13.798	491.735	-0.028
June	0.712	0.390	1.823
July	0.040	0.384	0.104
August	0.454	0.370	1.229
September	0.419	0.380	1.103
October	-0.601	0.413	-1.457
November	0.411	0.360	1.143
December	-0.097	0.369	-0.262
LL	-55.367	64.561	-0.858
PS	-34.795	866.941	-0.040
SP	-30.269	6.996	-4.326
TR	-3.140	2.954	-1.063
UN	-31.582	312.228	-0.101
TagBetyp	-2.318	0.340	-6.821
TagOTC	-1.062	0.740	-1.436
rLi:An	-0.008	0.001	-13.433
rLiTagBetyp	0.029	0.005	5.385
rLiTagOTC	0.024	0.013	1.828

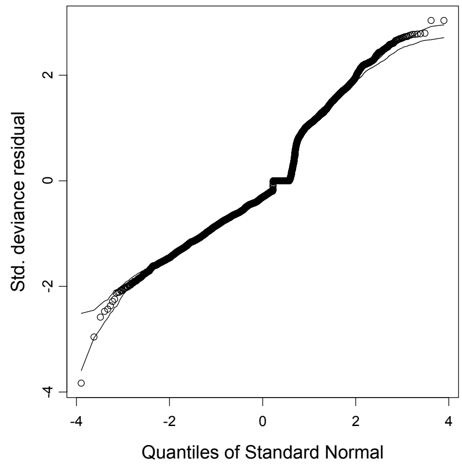

Figure 1. Quantile plots of the residuals from the final model for the probability of return rate for bigeye tuna with simulated confidence envelope.

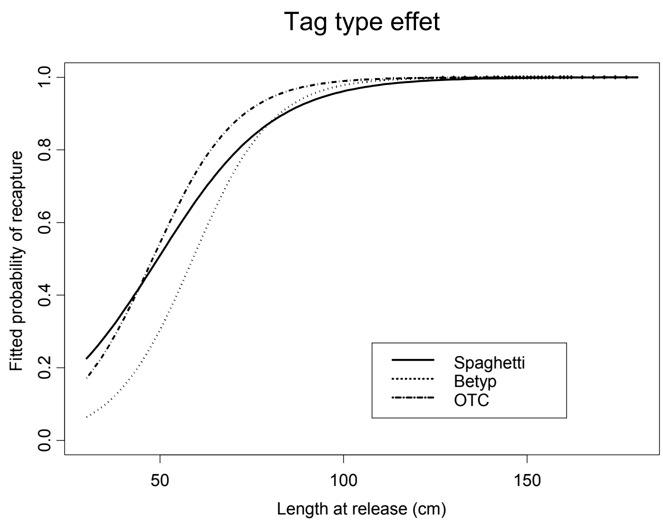

Figure 2. Example of the effect of the interaction between length at release and the kind of tag used (i.e., *rLi:Tag type*) on the recovery rate of bigeye tuna. The other factors were kept constant at *rLat=mean (rLat), rLon=mean (rLon), Gear="BB", Year=1996, Month="August"*, respectively. From this figure, it appears that the detrimental effect of the Betyp tag affects specifically the return rate of fish smaller than 80 cm.

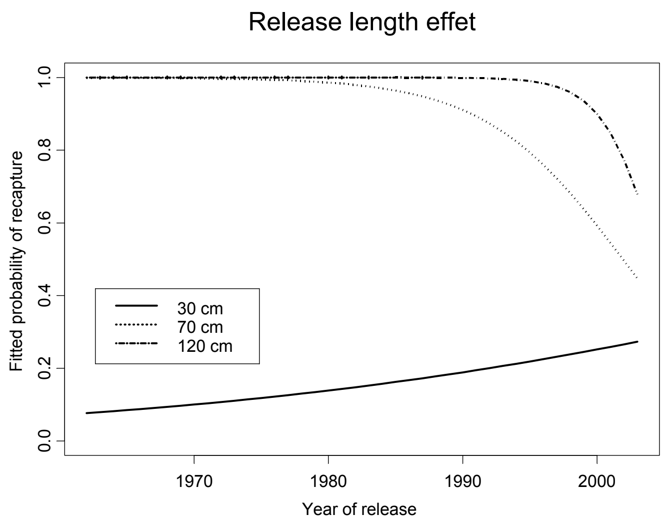

Figure 3. Example of the effect of the interaction between the year at release and the length at release (i.e., *rLi:Year*) on the recovery rate of bigeye tuna. The other factors were kept constant at *rLat=mean (rLat)*, *rLon=mean (rLon), Tag type = "Spaghetti", Gear="BB", Month="August"*, respectively.