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COMPARATIVE EFFICIENCY BETWEEN BETYP TAGS AND CONVENTIONAL TAGS

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Résumé

Dans le cadre d'un programme de marquage de thons, réalisé en 1999 à bord des canneurs basés à Dakar, deux types de marques ont été utilisés : les marques traditionnelles dites « spaghetti » et les marques employées par le programme BETYP (CICTA), de conception « pêche sportive ». Une comparaison des avantages et des inconvénients de chaque type de marque est présentée. Les analyses statistiques sont basées sur l'utilisation de GLM et de tests de randomization. Les taux et les lieux de recapture, les taux de croissance et les durées de liberté sont comparés selon les deux types de marques et pour trois espèces de thon (albacore, listao, patudo). Les résultats obtenus montrent une moindre efficacité des marques BETYP. En effet, le taux de recapture et la durée de liberté des patudos ainsi que le taux de croissance des albacores sont significativement plus faibles lorsqu'on utilise des marques de type BETYP. Il n'y a, par contre, pas de différence significative pour ces paramètres entre les deux types de marque pour le listao. Enfin, la mise en œuvre des marques BETYP se révèle peu adaptée aux grands programmes de marquage de thons tropicaux où il est nécessaire de marquer le plus grand nombre possible de poissons dans un délai de temps limité.

Abstract

During a tuna tagging program, conducted on board Dakar baitboats in 1999, two types of tags were used: the conventional "spaghetti" tags and the tags used by BETYP tagging program (ICCAT) from "sport fishing" design. Advantages and disadvantages of each type of tags are presented. Statistical analysis are based on GLM and randomization tests. Return rates, recapture's locations, growth rates and times at liberty are compared between both tags for three tuna species (yellowfin, skipjack and bigeye). Results conclude to a lower efficiency of BETYP tags. For instance, recapture rate and time at liberty for bigeye as well as growth rate for yellowfin are significatively lower when one uses BETYP tags. However, there is no significative difference between the two types of tags for these parameters for skipjack. Finally, the implementation of BETYP tags is not well suited to intensive tropical tuna tagging programs, as it is then necessary to tag the greatest possible number of fish during a limited time period.

MOTS-CLES

GLM, tagging, tagging mortality, bait boat, yellowfin, skipjack, bigeye

1. INTRODUCTION

From 1996 to 2000 a research program, called MAC for "Mattes de thons Associées aux Canneurs", was conducted on the peculiar fishing technique used by the bait boat fleet based in Dakar, Senegal (Hallier *et al.*, 2001). This technique, which consists of keeping a permanent association between the fishing boat and the fished tuna school, is described by Fonteneau and Diouf (1994) and Hallier and Delgado (2000). One of the main working tools used by this program was ordinary tagging. In 1999, two different types of tags were used: the conventional "spaghetti" tags used by all large tagging programs of the last thirty years and a new tag designed for opportunistic tagging of tunas and billfishes by the sport fishermen (Figure 1). Both tags are manufactured in the USA by Floy tag and manufacturing inc. Despite the fact that MAC tagging operations were performed on commercial operated fishing bait boat and not on bait boat specifically chartered for tagging, the aim of the program was to tag as many fish as possible. It is therefore interesting to compare the two different tags in term of their implementation on board bait boat especially with an objective of massive tagging, their performances in term of tag recapture rates and other relevant aspects.

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2. MATERIALS AND DATA

Conventional and new designed tags were provided by ICCAT. The second being adopted by the Bigeye Tuna Year Program (BETYP) is called, in the rest of the text, BETYP tag in opposition to the conventional tag. During MAC program, 10086 tunas were tagged. Up to July 1999 and in 2000, only conventional tags were used (6346 conventional tags). Then, during three tagging trips of 1999, both tags were used (2838 conventional tags and 902 BETYP tags). Among these 2838 conventional tags, 375 were put on tuna that also received an injection of oxy-tetracycline in order to study the rate of calcium deposit on their otoliths for growth study. Rewards for tuna recapture tags and the associated data were much higher when oxy-tetracycline injected fish were returned together with the tag. Therefore, these tags are not included in this comparative study.
During the first studied trip, labelled 25, 1073 tunas were tagged with conventional tags and 275 with BETYP tags. During trip 26, the corresponding tagging records are 700 and 225 and for trip 27, 690 and 402 (Table 1). Tagged tunas are skipjack, juvenile yellowfin and bigeye and tagging occurred off the Mauritanian coast in a square from 16°N to 21°N and 16°30W to 19°30W and from August to December 1999. Three different scientists have tagged but for a given trip, the same scientist has tagged all tunas during several tagging operations.
Commercial fishing generally started early morning and tagging operations could take place once fishing was over and crew free from any other tasks. Therefore, most tagging operations took place between mid-morning and mid-day or between 3 p.m. to 6 p.m.

3. METHODS

Tag recapture rate is calculated as the percentage of recaptured fish over the total number of tagged fish. When recaptures are made, the location of the discovery of the tagged tuna is recorded such as on board, at quay or in cannery. These data give information on the spotting quality of the tag and the awareness of the tag inventors.
Growth rates have been estimated from tag recapture according to the type of tags. The growth rate is calculated as the difference between the size at recapture minus the size at tagging divided by the time at liberty (days spent between tagging and recapture). It is expressed in mm/day or in cm/month. Recapture for fish at liberty for less than 20 days have not been considered as well as fish with growth less than –2 cm. The first limitation is to take into account a possible stress of the fish that will disrupt the growth and slight measurement errors as tuna were measured directly on the tagging cradle. The second limitation is directly related to measurement's errors that can be done negatively or positively.

3.1. Statistical tests for comparison of recapture rates

The analysis of the recapture rate between both types of tags may be biased due to differences in biological parameters between the tuna species (mortality, migrations) and in the trip effects (season of the tagging operation, technician effect, boat effect, etc). Accounting for these factors can be tentatively done with the use of generalized linear models (GLM). To explore the relationship between the variable of interest (the type of tag), several covariates (the different species of tuna, the trip number) and their respective interactions on the recapture rate (the dependent variable), logistic regression model may be helpful.

Multiple logistic regression is frequently used to build models that predict the probability of a recapture ($y_i = 0$ for a fish tagged and not recaptured, and $y_i = 1$ for recapture), as a function of a set of explanatory variables x_i. The logistic regression function assumes that the conditional mean of y_i, given a set of x_i, can be formulated as

$$E(y_i \mid x_i) = \pi(x_i) = \mathrm{Prob}(y_i=1 \mid x_i) = \frac{\exp(\beta_0 + \Sigma\beta_i x_i)}{1 + \exp(\beta_0 + \Sigma\beta_i x_i)},$$

where x_i is the covariate vector and β_i is the unknown coefficient vector. β_i is estimated by maximizing the log-likelihood function

$$LL(\beta) = \sum_{i=1}^{n} \{ y_i \,\mathrm{Log}[\pi(x_i)] + (1-y_i)\,\mathrm{Log}[1-\pi(x_i)] \}.$$

The link function, which gives the properties of a linear regression model, is called the logit (namely, the log odds transformation), where $g(x_i) = \mathrm{Log}[\pi(x_i) / (1-\pi(x_i))] = \beta_0 + \Sigma\beta_i x_i$; Hosmer and Lemeshow (1989); Agresti (1990).

Because the odds are defined as the ratio of the probability that an event occurs [$\pi(x_i)$] to the probability that it does not occur [$1-\pi(x_i)$], the odds ratio (ψ) is more easily interpretable than the estimated coefficient (β). It summarizes net impacts of predictors by indicating the multiplicative impact on the odds for a unit increase in a given predictor, net of all other covariates in the model (Agresti 1990). For categorical predictors entered as a series of dummy variables, a unit increase is equivalent to being in the category coded 1 on a given dummy variable as opposed to being in the category coded 0. Applied to the tagging data, the odds ratio is

$$\Psi = \frac{\text{P (recapture / x=1) / P (not recaptured / x=1)}}{\text{P (recapture / x=0) / P (non-recaptured / x=0)}}$$

where P (recapture / x=1) is the proportion of events that lead to a recapture, given that the explanatory variable x equals 1.

The objective in model building is 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). The search for the number of parameters that minimize both functions of bias and variance may be done with the aid of the Akaike's information criterion (AIC). Consequently, the model with the smallest AIC is defined as the parsimonious model (Lebreton *et al*, 1992, Anderson *et al*, 1994). As a result, the estimates provided from the parsimonious model are used to perform the "adjusted" recapture rates (i.e., accounting for the effects due to the explanatory variables).

The model encompasses the following main factors:
- Species (BET, SKJ, YFT)
- Type of tag (BETYP, Conventional)
- Trip number (25, 26, 27)
- and their respective interactions.

Categorical variables were set up such that all levels were contrasted with a reference level to ensure that the design matrix was of full rank. For the factors "Species", "Tag type" and "Trip" the reference levels were bigeye, BETYP tag and trip 25, respectively.

3.2. Statistical test for comparative analysis of the growth rate and the time at liberty

Bearing in mind that the number of recaptures was weak for some species of tunas, a comparison of the growth rate and the time at liberty between both types of tags based on the difference between the sample medians is more robust than based on the difference between the sample means. The question addressed is to check whether a difference in medians indicates a significant pattern in the data or if this is purely due to chance. In such a situation, randomization testing is a way of determining whether the difference in the observed data is just one of the equally likely to have occurred (H_0), or not. Basically a randomization test is defined as a procedure that involves comparing an observed test statistic with a distribution that is generated by randomly reordering the data values in some sense (Manly, 1997). The significance level of the difference in medians of the observed data is the proportion of generated differences that are larger than this value in the randomization distribution. Randomization tests have the advantages to be valid even without random samples and easy to apply in case of non-standard test statistics (e.g., comparing two sample medians). Because it could be argued than time at liberty (used as an indicator of the mortality rate) can not be only assessed by the comparison of the medians, we used the Kolmogorov-Smirnov two samples test (thereafter, *ks*) to compare the whole frequency distributions of the time at liberty between both type of tags.

4. RESULTS

4.1. Tag recapture rates

The recapture rates by type of tags, tagging operations and by species are given in table 2. A summary by trip is given in table 1. Regardless of species and trip, the recapture rate is lower for BETYP tags (34.8 %) than for conventional tags (40 %) (Table 1). At the trip level, BETYP tag recapture rates are much lower than conventional recapture rates for trips 26 and 27 but higher for trip 25. At the species level and all trips together, BETYP tag recapture rates are always much lower than conventional tag recapture rates. When one goes down

to the level of species and trips, BETYP tag recapture rate is higher than conventional tag recapture rate for trips 25 and 27 for skipjack and for trip 26 for yellowfin (Table 1); in the other cases, it is lower. If only the tagging operations when both tags were used are considered (Table 2), BETYP recapture rates for yellowfin are 2 times lower and never higher than conventional recapture rates; for skipjack, it is 3 times higher and 1 time lower and for bigeye, it is 4 times lower, one time equal and never higher. It should be pointed out that the recapture rates are very different according to species. For the all MAC program, the recapture rates are 53.2 % for yellowfin, 19.1 % for skipjack and 37.7 % for bigeye. Therefore, when results are pulled together for different species, the final recapture rates between the different tags will greatly depend on the species composition of the tagged fish as well as on the trip number. In order to account for this variability, a statistical analysis was performed.
The analysis of the deviance table resulting from the stepwise selection procedure is presented in table 3. It is quite clear that among the three main factors and their three interactions, only the interaction "Trip * Type of tag" is not significant. This result means that the difference in recapture rate observed between the two types of tags is not affected by the trip number (or by any type of underlying effect related with it; e.g. the bait boat rented for the tagging operations, the technician in charge of a specific tagging trip, etc). In contrast there was significant interactions between the tuna species and the trip effect (likely due to differences in biological behaviour between the tuna species over the fishing season) and between the tuna species and the tag type (this point will be discussed in the Discussion section).
The smallest AIC, and as a consequence the parsimonious model, was reached for:

$$\text{logit} = g\ (\text{tAg} = a; \text{Species} = s; \text{Trip} = t) = \beta_0 + \beta_{1(a)} + \beta_{2(s)} + \beta_{3(t)} + \beta_{4(as)} + \beta_{5(ts)}\,.$$

The model selected fitted well the data (the speudo-R^2 = 0.98). The estimated recapture rates (i.e., the adjusted values accounting for the associations among the explanatory variables) are presented in parallel with the unadjusted values in table 1. Estimated coefficients (β), estimated standard errors, and t-values from this model are provided in table 4. For instance, the estimated coefficients (β) for the variable Species (S) represent the logs of the odds (Ψ) for each species, using bigeye as reference level (S_0). In the present analysis, the estimated coefficients for this variable were: log[Ψ(Skipjack, bigeye)] = -1.882, and log[Ψ(yellowfin, bigeye)] = 0.565. (Table 4). The corresponding odds ratio and the confidence intervals (C. I.) can be obtained directly by exponentiation: $\Psi = \exp(\beta)$ and C. I. = exp [$\beta \pm z_{1-\alpha/2}$*S.E.(β)].

From table 4, at first glance, it may be observed that "on average" the recapture rate occurred twice as often when conventional tags were used than when BETYP tags were used (i.e., $\exp^{(0.652)} = 1.92$). However, as seen in the structure of the model selected, the factor "Tag type" (A) was interacting with the species of tuna (S). Consequently, because the effect of A on the outcome variable depended on the level taken by S (and reciprocally), a direct interpretation of these values remains problematic. For estimating odds ratios in the presence of interaction, first we express the estimated logit for the different combinations of values of S = s, A = a, and holding the remaining variable Trip and its interactions constant = z :

$$g\ (A = a; S = s; z) = \beta_0 + \beta_{1(a)} + \beta_{2(s)} + \beta_{4(as)} + \beta'_{(z)}\,.$$

The logit differences were computed only among the types of tag. For instance, the log-odds for A=1 (i.e., conventional tag) versus A=0 (i.e., BETYP tag) with S held constant at S=0 (i.e., bigeye) is:

$$\begin{aligned}\text{Ln}\ [\Psi(A = 1; A = 0; S = 0; z)] &= g\ (A = 1; S = 0; z) - g\ (A = 0; S = 0; z) \\ &= (\beta_0 + \beta_{1(a)} + \beta'_{(z)}) - (\beta_0 + \beta'_{(z)}) = \beta_{1(a)}\end{aligned}$$

The calculations for the logit differences in terms of the estimated parameters for the six possible combinations of the values of the types of tags and the tuna species are reported in table 5. The calculations of the corresponding variances follow the basic rules for calculating the variance of a linear combination of related variables. The endpoints of the confidence interval for the odds ratio are performed by exponentiation of the limits estimated for the log-odds.

The values of the estimated logit differences, odds ratios and 95% C.I. for the three tuna species are provided in table 6. The interpretation of the estimated odds ratio give us the evidence that for bigeye, the recapture rate using conventional tags was statistically higher than the recapture rate using BETYP tags (the odds ratio increased approximately by two). For yellowfin, the odds ratio was not as impressive, but the width of the confidence intervals indicates that there is a considerable uncertainty in this estimate, hence the effect, while not statistically significant, may be important. The apparent lack of statistical significance of this odds ratio may be due to the relative low number of yellowfins tagged (and consequently recaptured). To check this assumption (i.e., type II error), we calculate the minimum sample size consistent with the desired α level (i.e., the probability of rejecting H_0 when H_0 is true = type I error) and power (i.e., the power of the test is its ability to correctly reject the null hypothesis = 1 - Pr (type II error)). Assuming the observed difference between both recapture rates (0.112), for the traditional level values used for α (0.05) and for power (0.80), the sample sizes should be 417 for the conventional tags and 165 for the BETYP tags. In the same way of idea for the sample sizes observed in this study for yellowfin (and holding α at 0.05 and d at 0.112) the power of the binomial test drops to 0.14, showing its low capacity to reject H_0. That means that the probability of not rejecting H_0 when in fact H_0 is false (i.e., committing a type II error) is very large (86 %). Consequently, the sample size was too weak to conclude that the recapture rate for both types of tags was similar for yellowfin. In contrast, for skipjack we cannot reject the hypothesis that the type of tags used did not influence the recapture rate.

4.2. Recapture locations

The distribution of the recapture locations according to the type of tags is given in table 7. This distribution is almost similar whatever the type of tags. More than 9 recapture tags out of 10 (93 % for BETYP tags and 93.8 % for conventional tags) are spotted by the fishermen on board the vessel either immediately when the fish are pulled on board or lately when they are tossed into freezing holds. Between 5.2 % (for conventional tags) and 6.1 % (for BETYP tags) are spotted while unloading the fish in port and 1 % only is spotted in canneries. Therefore, the location's distribution of the tags does not depend on the type of tags.

4.3. Recapture tags with or without their heads on?

When tags are returned it is not rare that the attached part of the tag or head is missing either this part breaks down when the tag is pulled out of the fish or the inventor cuts the tag onto the fish because he cannot pull it out. The proportions of tags recovered with or without their heads are given in table 8. For conventional tags, 89.4 % are recovered with their heads on, while only 60.4 % of the BETYP tags have still their heads on. These proportions vary greatly between the different sets. If we consider only the sets where at least more than 5 tags are collected, the percentage of tags with head is 9 times higher for conventional tags than for BETYP tags and only 3 times lower.

A Khi² test was performed and gave X-square = 94.0745, df = 1, p-value = 0, a very significative result that BETYP tags lost their heads much more often than conventional tags.

4.4. Growth rates

The medians of growth rates according to type of tag are given in table 9. Growth rate is higher for BETYP tags than for conventional tags for skipjack but it is lower for the two other species, especially for yellowfin. For this species, the median of the growth rate equalled 1.351 for the conventional tags and 0.406 for the BETYP tag. Is there any evidence of a difference in the median growth rates for the two types of tags? The answer is provided by the randomization test, which indicates that under the hypothesis H_0 only 1.44 % of the generated differences are more extreme than the observed difference of 0.945. Hence, this provides some evidence that the null hypothesis is not true, and, by implication, that the BETYP tags stunted the growth rate for yellowfin. However, because the number of fishes recaptured is weak (15 yellowfins), the conclusion, which can be drawn from this study, is limited and need to be confirmed by additional comparative tagging operations.

For skipjack, the growth rates were 0.384 and 0.489 for conventional and for BETYP tags respectively. There are 30.8 % of generated differences greater than the observed difference (d = –0.105). Consequently, we cannot reject the hypothesis than the observed pattern is a purely chance effect.

For bigeye tuna, the observed growth rate was higher for the conventional tags than for the BETYP tags (0.790 versus 0.672). However, the result of the randomization test shows that around one forth of the differences (25.9 %) obtained after distributing each data at random in the two types of tags are larger than the observed difference in medians (d = 0.118). Thus, there is not evidence against the null hypothesis H_0.

4.5. Time at liberty

In general, when one considers that the fish are not migrating, a difference in the time at liberty between species can express a difference in mortality rates (i.e. the species dying the most will have less probability to register long time recapture). In the same way, a difference in time at liberty by tag type can be interpreted as a difference in mortality rates.

The median of time at liberty for yellowfin tagged with conventional tags was 52 days against 38 days for those tagged with BETYP tags. As seen previously for the analysis of the recapture rates, the fact that the observed difference in medians (d = 14) was not significant (*ks* = 0.5; p = 0.292) is likely due to the low power of this test

(because of the low number of fishes tagged). However the randomization test led to an acceptation of the lack of effect between both types of tags (p = 0.326).
The medians of times at liberty were 11 and 12.5 days respectively for conventional and for BETYP tags (for the randomization test, d = -1.5, p = 0.522) for skipjack. The absence of a difference based on the medians test was also found for the comparison of the cumulative frequency distributions (*ks* = 0.164; p = 0.552). Apparently, the BETYP tags did not affect the survival rate of skipjacks.
In contrast the results showed significant differences between the types of tag for bigeye. The medians of the times at liberty were 66 days and 41 days for the conventional tags and for the BETYP tags respectively. There was only 0.5 % chances that the pattern observed (d = 25 days) was a purely chance effect. Assuming that, once released, the tagged fishes were redistributed at random in the sea and that the fishers reported the tags independently of the type of tag, we can conclude that a bigeye tagged with a BETYP tag had “on average” a time at liberty 25 days lower than a bigeye tagged with a conventional tag. Comparing the frequency distributions of time at liberty (*ks* = 0.210; p = 0.004), it appears that in proportion this difference with bigeye tagged with conventional tags occurred during the first month following the release. This does not mean that their catchability was larger during the first month but that they were likely subject to larger mortality in the following months (i.e., a way of explaining that the probability of recapturing a fish tagged with a BETYP tag decreased thorough time).

5. DISCUSSION

5.1. Tag recapture rates

Conventional tags with their barbed head (Figure 1) were placed at the base of the second dorsal fin in order to get the barb tangled into the bones that join this fin to the central backbone of the fish. The target is to firmly attach the hook of the tag’s head into these bones (Figure 2). BETYP tags have a bigger head with one hook on each side; the head is joined to the corpse of the tag by two thin and strong nylon threads (Figure 1). Sport fishermen specifically designed this type of tag for opportunistic tagging of tuna and billfish especially when it is not possible to pull the fish on board to tag it. The tag’s head is hollow which permit to thread it onto the tagging needle attached to a long pole. So, the fish, still in the water alongside the boat, can be tagged. In this situation, it is not possible to set the tag at a precise location onto the fish’s body. Therefore, it is necessary the tag be well anchored to the body of the fish. The BETYP tag design is made to fulfil these requirements. In fact, when dead fish are tagged so, it is possible to lift up a fish of 2-3 kg by holding it by its tag. In contrast, with a fish wearing a conventional tag, the same experiment will often result in the dropping of the fish while the tag will remain in hand. In these conditions, one might assume that less BETYP tags will drop from the fish and therefore recapture rates would be higher with this type of tags than with the conventional tags. However, results do not confirmed this assumption. As mentioned previously, there is no tag’s effect on skipjack recapture rate, a likely tag effect on yellowfin but a larger number of tagged fish is necessary to confirm this effect. And there is a statistically significant tag effect for bigeye recapture rate. Hence, when a tag effect exists, it is not as expected: recapture rates are lower with BETYP tag than with conventional tags!
On the other hand, the only force exerted onto the tag is the water drag from the displacement of the tuna, which is minimal regarding the hydrodynamic shape of the tag and its small volume and weight. During MAC tagging operations, the targeted tagging location was the base of the second dorsal fin whatever the type of tags. Therefore a difference in the location of the tag into the body of the fish cannot be involved to explain the differences in tag recapture rates. The overall length of the two types of tags is very similar (13 cm for conventional tag and 15 cm for BETYP tag). The body of the tag that bears the tag number has the same diameter for both tags but is longer for conventional tag (11 cm) against 8 cm for BETYP tag as part of the BETYP length is accounted by the two thin nylon threads that tie together the head and the body. The total weight is 0.665 g for conventional tag and 0.775 g for BETYP tag. The diameter of the head is bigger for BETYP tag than for conventional tags: 6 mm against 4 mm. When the skin of the fish is punctured by these tags, the hole made into the flesh of the fish is bigger for BETYP tag than for conventional tag. Does this slightly bigger wound can result in a more difficult closing up of the wound with BETYP tags than with conventional tag? And consequently this will result in more dropping of BETYP tags and a lower recapture rate? The size distributions of the fish tagged using the two types of tags were 41 to 102 cm for conventional tagged fish and 39 to 89 cm for BETYP tagged fish. They were all small size fish (Figures 3 a & b) therefore the wound made by the tagging with BETYP tags might be too big for bigeye of such sizes and maybe also for yellowfin but not for skipjack.
When the recapture rates are plotted by size classes and by type of tags (Figure 4), they vary with size and with the type of tag. However, for small fish (with FL < 50 cm), the same results are found: small skipjack recapture rate is not different according to the type of tags (11.2% for conventional tags and 11.4% for BETYP tags, figure

4a). In contrast, small bigeye present a much lower recapture rate for bigeye tagged with BETYP tags (23.8%) as compared to bigeye tagged with conventional tags (36.5%), (Figure 4b). Without experiment in vivo it is not possible to conclude if the difference in recapture rate between the two tags is due to differences in the sizes and/or weight of the two tags.
The permanent association between tunas and bait boat gives the possibility to follow by eye individual tagged tunas swimming next to the side of the boat or better at the bow as one can observe dolphins swimming around a ship. Tagged tunas with conventional and BETYP tags have been observed during calm sea at the bow of the boat. The behaviour of BETYP tags is good (e.g., it stay well stabilized above the back of the fish). Therefore, its drag on the swim of the fish is certainly as minimal as with conventional tags and maybe even less.
Even if there is no assumption to explain the lower recapture rate of BETYP tags compared to conventional tags, this lower recapture rate still exists. This is all the more surprising because several factors should give the opposite result.

5.2. Recapture locations

It does not appear that BETYP will be more difficult to spot by fishermen than the conventional tags (Table 7). The BETYP tags are as well detected as the conventional tags, which is consistent with the fact that the body of the tag outside the fish is of the same colour for the two tags (yellow), the same diameter and almost the same length.

5.3. Recapture tags with or without heads on?

It can be seen that more BETYP tags are returned without heads therefore certainly more heads remain inside the fish body. This result is directly related to the better anchorage of the BETYP into the body of the fish. If tags are set at the base of the second dorsal fin there is probably little prospect that this part of the tag ends up inside a tuna can. This part of the body, made of bones and red muscles, is discarded when the fish is prepared at the cannery. For conventional tags, 10 % are returned without head and despite the fact that these tags have been used for many years and in great numbers one never heard that a tag's head has been found in a tuna can. Therefore, this risk remains minimal even for BETYP tags, if they are set at the base of the second dorsal fin.

5.4. Growth rates according to types of tags

The tag effect is noted for yellowfin: BETYP tags affect negatively growth rate. However, regarding the small size of the sample, more data are needed to confirm this result. For the two other species, there is no tag effect. As for the difference in recapture rate, it is difficult to explain this result. Either the bigger wound made by tagging with BETYP tags can affect the growth rate and consequently the recapture rate but only yellowfin are concerned. Only experiment in vivo can address this problem.

5.5. Time at liberty

There is no tag effect on the time at liberty for yellowfin and skipjack while bigeye with BETYP tags has a lower average time at liberty than with conventional tags. This effect is particularly evident the month following tagging. This could mean either that bigeye die more when they carry BETYP tags or that they migrate more often outside the fishing zone than the two other species. However, according to average distance travelled between tagging and recapture, bigeye appears as the less moving species: on average bigeye travel 1.16 miles per day, yellowfin 1.7 and skipjack 2.14. These results favour the hypothesis that bigeye would die more from being tagged with BETYP tags than with conventional tags. This is also in accordance with the fact that BETYP tags affects negatively recapture rates of bigeye.

5.6. Implementation of BETYP tags

In addition to the previous results, the implementation of BETYP tags is not as easy as for conventional tags. The conventional tags are easily stored in their needle and a hundred needles can be set up on a compact wooden block (30 x 10 x 10 cm). Because of their small size, these blocks are easily manageable. When the needle is tilted upside down the tag remains in place and the fish can be tagged easily.
The implementation of BETYP tags is not that simple. First, when the tags are in bunch, because of their two-barbed head and their two thin threads, they get more entangled together than conventional tags, so consequently it takes more time to sort them out. Secondly, it takes more times to set them on the needle as the head of the needle has to be thread into the tiny hole inside the middle of the tag's head (1 mm hole). While with conventional tag it is just necessary to slip the body of the tag inside the 3 mm hole of the needle. Thirdly, the

tag does not hold by itself onto the needle; if one turns the needle upside down the tag will fall immediately. Therefore it is necessary to have a system to hold the tag in place such as a rubber band. This is a manipulation phase that is not necessary with conventional tags. Quarterly, the needles of BETYP program were short, therefore it is not possible to use them directly and it is necessary to fix them to a wooden cylinder or another support. The needle attached to the wooden cylinder takes a lot more room therefore it is not possible to prepare in advance a great number of them and to put them at the disposal of the tagger. Accordingly, more people are needed during the tagging operation to prepare the tags and to make them regularly available to the tagger. With conventional tags, it is easy to have more than one thousand tags ready for tagging; this represents 10 blocks easy to store and to transport. Therefore while using conventional tags, all the scientific personnel on board can tag but with BETYP tags at least half of the team is busy on filling the needles with tags, bringing them regularly to taggers and bringing back empty needle. If fishing is fast more than one servant for each tagger is necessary while with conventional tags none is needed.
On a pole-and-line boat to catch tuna an active response of the tunas to baiting and hooking is needed. This response rarely last a long time but it is generally strong. Therefore, it is possible to catch a lot of tuna during a short time. In order to tag them, the tagger will need to be very fast, very efficient, and many taggers will be needed. According to the different characteristics of the two tags, BETYP tags are not fit for a large tagging program.

6. CONCLUSIONS

The main results from that study is that BETYP tags in general do not result in better recapture rates, growth rates or time at liberty than conventional tags. Even comparative analysis, based on GLM and randomization tests, showed that BETYP tags have a negative impact on bigeye for the recapture rate and the time at liberty. This can be the expression of a higher mortality rate by the BETYP tags. For yellowfin, the small number of tagged fish does not permit to be affirmative but nonetheless the statistical tests indicate more a negative impact for recapture rate, for growth rate and for time at liberty than no effect. Only for skipjack, the type of tag has no effect on the different parameters tested despite the fact that it is the smallest size tuna. Therefore, when negative effects do exist, recapture rates, growth rates or time at liberty should be corrected accordingly. Few assumptions are made to explain these results but to test them will need in vivo experiments in seawater tanks.
BETYP and conventional tags are equally correctly spotted on board by the fishermen and secondly in port or at canneries. Many more BETYP tags than conventional tags are reported without their head, which can result in heads finding their way up to tuna cans, especially when tags are placed outside the base of the second dorsal fin. Furthermore the implementation of this tag is not well suited for large and fast tagging operations. They seem well suited to opportunistic tagging for sport fishermen, as they were designed for, but they lack several characteristics necessary for a large tuna-tagging program and do not bring additional advantages.

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Table 1 : Number of tagged and recaptured fish and recapture rates by species, trip and type of tag and estimated GLM recapture rates.

Trip number	Tag type	Tagged	Recaptured	% recapture	% r. estim.
		YELLOWFIN			
25	Conventional	49	42	85.7	84.0
	BETYP	12	8	66.7	73.5
26	Conventional	11	8	72.7	80.2
	BETYP	12	9	75.0	68.1
27	Conventional	1	0	0.0	0.0
	BETYP				
TOTAL	Conventional	61	50	82.0	
	BETYP	24	17	70.8	
		SKIPJACK			
25	Conventional	825	154	18.7	19.4
	BETYP	153	36	23.5	19.4
26	Conventional	299	34	11.4	8.9
	BETYP	126	4	3.2	8.9
27	Conventional	183	61	33.3	33.8
	BETYP	18	7	38.9	33.8
TOTAL	Conventional	1307	249	19.1	
	BETYP	297	47	15.8	
		BIGEYE			
25	Conventional	199	150	75.4	75.2
	BETYP	110	67	60.9	61.2
26	Conventional	390	285	73.1	72.7
	BETYP	87	49	56.3	58.1
27	Conventional	506	252	49.8	50.2
	BETYP	384	134	34.9	34.4
TOTAL	Conventional	1095	687	62.7	
	BETYP	581	250	43.0	
		TOTAL			
25	Conventional	1073	346	32.2	
	BETYP	275	111	40.4	
26	Conventional	700	327	46.7	
	BETYP	225	62	27.6	
27	Conventional	690	313	45.4	
	BETYP	402	141	35.1	
TOTAL	Conventional	2463	986	40.0	
	BETYP	902	314	34.8	

Table 2 : Number of tagged and recaptured fish and recapture rates by species and by type of tag for the fishing operations when both tags were used.

			YELLOWFIN			SKIPJACK			BIGEYE		
Trip N°	Operation N°	Tags type	N° tagged	N° recapt.	Recap. Rate	N° tagged	N° recapt.	Recap. Rate	N° tagged	N° recapt.	Recap. Rate
25	11	Conv.				260	36	13.8	1	1	100.0
25	11	Betyp				25	11	44.0			
25	15	Conv.				99	13	13.1	1	1	100.0
25	15	Betyp	1	0	0.0	47	10	21.3	2	2	100.0
25	21	Conv.				100	24	24.0			
25	21	Betyp	5	5	100.0	81	14	17.3	14	7	50.0
25	24	Conv.	1	1	100.0	73	26	35.6	14	8	57.1
25	24	Betyp	2	1	50.0				26	11	42.3
25	25	Conv.	23	22	95.7	2	0	0.0	143	112	78.3
25	25	Betyp	4	2	50.0				68	48	70.6
26	17	Conv.				100	21	21.0	56	42	75.0
26	17	Betyp	9	7	77.8				47	32	68.1
27	19	Conv.	1	0	0.0	11	5	45.5	148	59	39.9
27	19	Betyp				4	2	50.0	95	30	31.6

Table 3. Stepwise selection process for the logistic model used to fit the recapture rate with respect to the species (BET, SKJ, YFT), the Trip effect (25, 26, 27), the type of the tag (Conventional, BETYP type) and their respective interactions. Terms were added sequentially (first to last).

Effect	Df	Dev.Res.	Df	Res.Dev	Pr(Chi)
NULL			16	800.97	
Species	2	567.60	14	233.37	0.00
Trip	2	56.54	12	176.83	0.00
Tag Type	1	44.00	11	132.83	0.00
Species:Trip	4	111.62	7	21.20	0.00
Species:Type	2	9.17	5	12.04	0.01
Trip:Type	2	3.45	3	8.58	0.18

Table 4 Estimated coefficients (β), estimated standard errors, and t-values, for the multivariate model selected to assess the variability in the logit of the recapture rate. All variables were treated as categorical.

Coefficients:	Value	Std.Error	t value
(Intercept)	0.457	0.141	3.235
SKJ	-1.882	0.222	-8.465
YFT	0.565	0.573	0.985
Trip26	-0.131	0.163	-0.804
Trip27	-1.102	0.143	-7.697
Tag Type	0.652	0.110	5.957
SKJTrip26	-0.767	0.250	-3.070
YFTTrip26	-0.131	0.640	-0.204
SKJTrip27	1.854	0.222	8.340
YFTTrip27	-8.761	36.659	-0.239
SKJTagType	-0.650	0.210	-3.091
YFTTagType	-0.013	0.611	-0.021

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Table 5 Expressions of the logits, logits differences and corresponding variances in terms of the estimated parameters (see Hosmer and Lemeshow ; 1989, p. 102-104).

	Species		
Tag type	0 (BET)	1 (SKJ)	2 (YFT)
0 (BETYP)	$\beta_0 + \beta'_{(z)}$	$\beta_0 + \beta_{2(s1)} + \beta'_{(z)}$	$\beta_0 + \beta_{2(s2)} + \beta'_{(z)}$
1 (Conventional)	$\beta_0 + \beta_{1(a)} + \beta'_{(z)}$	$\beta_0 + \beta_{1(a)} + \beta_{2(s1)} + \beta_{4(a\ s1)} + \beta'_{(z)}$	$\beta_0 + \beta_{1(a)} + \beta_{2(s2)} + \beta_{4(a\ s2)} + \beta'_{(z)}$
Logit difference	$\beta_{1(a)}$	$\beta_{1(a)} + \beta_{4(a\ s1)}$	$\beta_{1(a)} + \beta_{4(a\ s2)}$
Variance	$Var(\beta_{1(a)})$	$Var(\beta_{1(a)}) + Var(\beta_{4(a\ s1)}) + 2\ Cov(\beta_{1(a)}\ \beta_{4(a\ s1)})$	$Var(\beta_{1(a)}) + Var(\beta_{4(a\ s2)}) + 2\ Cov(\beta_{1(a)}\ \beta_{4(a\ s2)})$

Table 6 Estimated logit differences, Odds ratios (ψ), 95 % Confidence intervals (C.I.) for the tag type effect among the different species of tuna.

Tuna species	Logit diff.	Odds ratio	Upper C.I.	Lower C. I.
BET	0.652	1.920	2.380	1.549
SKJ	0.002	1.003	1.425	0.705
YFT	0.639	1.895	6.154	0.584

Table 7 : Distribution of the recaptures according to the discovery locations

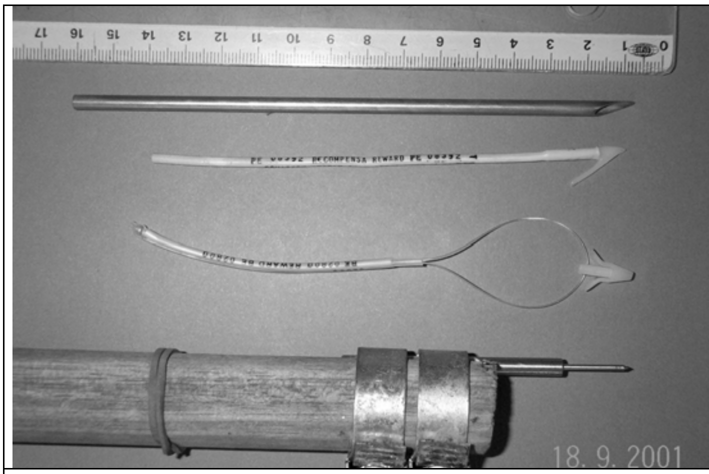
		Number			Percentage		
Tags' type	Trip Number	On board	In port	In cannery	On board	In port	In cannery
Conventional tags	25	311	29	6	89.9	8.4	1.7
	26	310	13	4	94.8	4.0	1.2
	27	304	9	0	97.1	2.9	0.0
	Total	925	51	10	**93.8**	**5.2**	**1.0**
BETYP tags	25	104	6	1	93.7	5.4	0.9
	26	55	7	0	88.7	11.3	0.0
	27	133	6	2	94.3	4.3	1.4
	Total	292	19	3	**93.0**	**6.1**	**1.0**

Table 8 : Number and percentage of tags returned with or without their head on according to the type of tag

Dates when tags are returned	Conventional tags		BETYP tags	
	With head	Without head	With head	Without head
25/08/99	54	3	2	2
30/09/99	26	8	6	2
08/10/99	15	1	2	1
19/10/99	35	4	14	1
28/10/99	39	0	10	6
12/11/99	50	7	5	8
06/12/99	30	10	4	3
13/12/99	16	8	3	1
29/12/99	122	8	10	32
13/01/00	10	5	2	5
27/01/00	45	1	13	5
01/02/00	12	0	5	0
07/02/00	55	0	24	6
17/02/00	10	2	8	1
15/03/00	20	9	6	6
13/04/00	2	6	3	3
03/05/00	33	0	1	0
19/05/00	3	0		
02/06/00	11	0	1	0
29/06/00	11	1	1	0
03/07/00	1	0	1	0
17/07/00	17	0	2	1
30/08/00	10	1	5	1
TOTAL	**627**	**74**	**128**	**84**
Percentage	**89.4**	**10.6**	**60.4**	**39.6**

Table 9 : Growth rate according to the type of tag.

	Number of fish		Mediane of growth rate (in mm/day)	
	Conventionnel	Betyp	Conventionnel	Betyp
Yellowfin	9	6	1.351	0.406
Skipjack	31	10	0.384	0.489
Bigeye	126	44	0.790	0.672



Scale in cm

Tag applicator for conventional tag

Conventional tag

BETYP tag

Tag applicator for BETYP tag tied up on a hand pole on which a rubber band is set to avoid the dropping of the tag

Figure 1 : Conventional and BETYP tags and their applicators

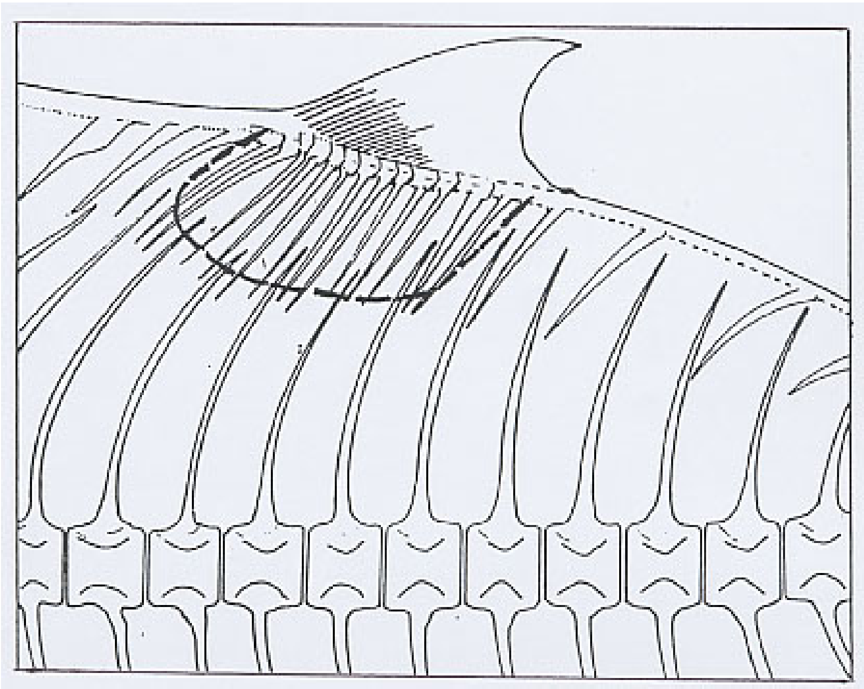


Figure 2 : Location on the back of the tuna where conventional and BETYP tags where set during MAC tagging operations.

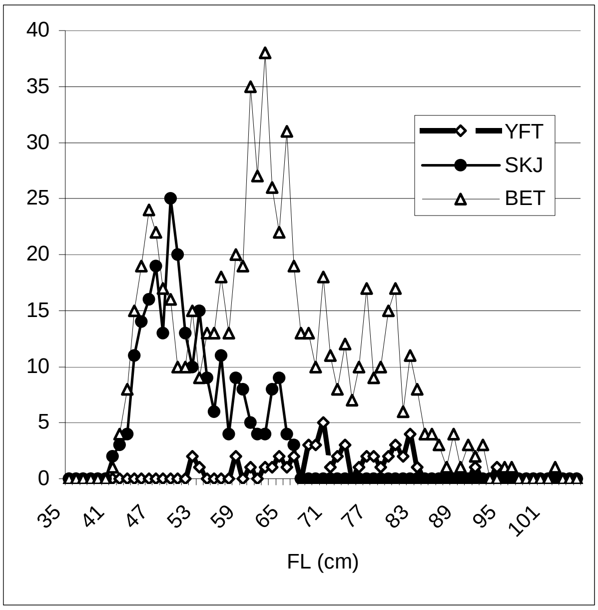


Figure 3a : Tagged tuna frequency distributions for conventional tags

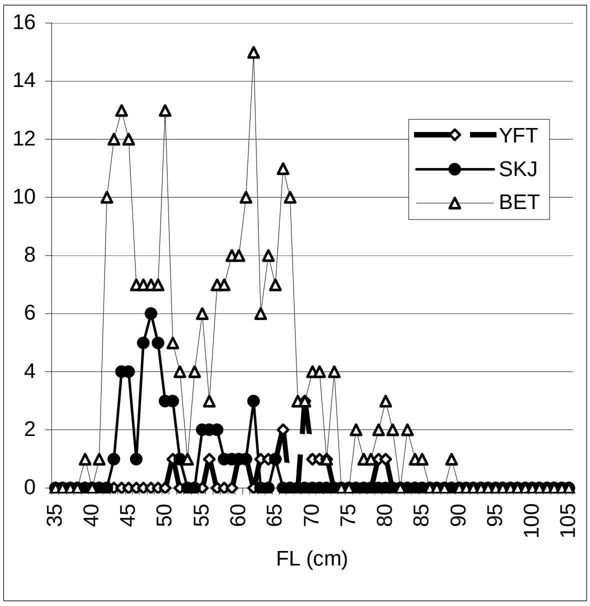


Figure 3b : Tagged tuna frequency distributions for BETYP tags

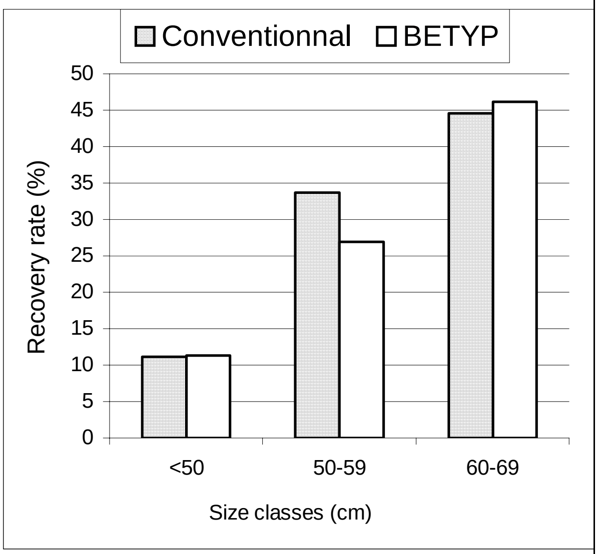


Figure 4a : Skipjack recapture rates with length and type of tag

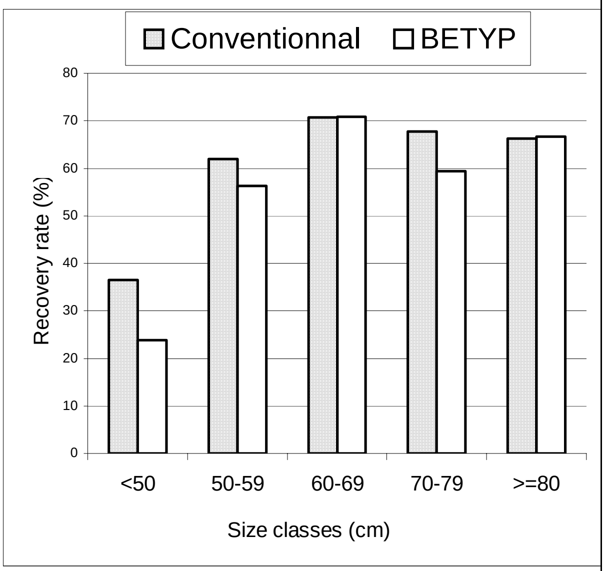


Figure 4b : Bigeye recapture rates with length and type of tag