SCRS/2001/42 Col.Vol.Sci.Pap. ICCAT, 54 (2): 353-362. (2002)

DESCRIPTIVE ANALYSIS OF THE ICCAT BLUEFIN TUNA TAGGING DATABASE

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SUMMARY

The present paper proposes a simple descriptive analysis of the ICCAT bluefin tuna tagging database. Since 1954, about 91.2% of the tags were released in the West Atlantic and 8.8% in the East Atlantic. The great majority of tags was recaptured in their area of release, i.e., 95.7% and 97.25% for the East and the West Atlantic, respectively. The number of tags released in the West and recaptured in the East (102) was about 5 times higher than the reverse (19), but the percentage of transatlantic migrations from East-to-West (4.3%) was about 2 times higher than the one from West-to-East (2.25%). The percentage of transatlantic migrations varies over time, especially from West-to-East. It was much higher during the 90's (7.6%) than in the three previous decades (0.8% to 2.3%). The probability to get a recapture in another area than the one of release seems further to depend on two factors: (i) the time at liberty and (ii) the age (or size) of the fish; higher the time at liberty and/or older the fish, higher the probability to get a transatlantic migration.

RESUME

Cet article propose une simple analyse descriptive de la base de données marquage de thon rouge du CICTA. Depuis 1954, environ 91.2% des marques ont réalisées dans l'Atlantique Ouest et 8.8% dans l'Atlantique Est. La grande majorité des marques a été recapturée dans leur zone de marquage, i.e., 95.7% et 97.25% pour l'Est et l'Ouest. Le nombre de marques réalisé dans l'Ouest et recapturé dans l'Est (102) était environ 5 fois plus important que l'opposé (19), mais le pourcentage de migrations trans-atlantiques d'Est en Ouest (4.3%) était environ 2 fois plus important que celui d'Ouest en Est (2.25%). Le pourcentage de migrations trans-atlantiques varie dans le temps, en particulier d'Ouest en Est, où il fut bien plus fort dans les années 1990 (7.6%) que durant les 3 décades précédentes (0.8% à 2.3%). La probabilité d'obtenir une recapture dans une autre zone que celle du marquage semble de plus dépendre de 2 facteurs : (i) le temps de liberté et (ii) l'âge (ou la taille) du poisson ; plus long est le temps de liberté et/ou plus âgé est le poisson, plus importante est la probabilité d'obtenir une migration trans-atlantique.

RESUMEN

El presente documento propone un simple análisis descriptivo de la base de datos de marcado del atún rojo de ICCAT. Desde 1954, se han colocado el 94,2% de las marcas en el Atlántico oeste y el 8,8% en el este. La gran mayoría de las marcas se recuperaron en la zona en que fueron colocadas, es decir, 95,7% y 97,25% para el Atlántico este y oeste, respectivamente. El número de marcas colocadas en el Oeste y recuperadas en el Este (102) fue el quíntuple que la inversa (19), pero el porcentaje de migraciones trasatlánticas de Este a Oeste (4,3%) duplicó al porcentaje de las del Oeste al Este (2,25%). El porcentaje de migraciones trasatlánticas varía en el tiempo, especialmente del Oeste al Este, donde fue mucho más elevado en los 90 (7,6%) que en las tres décadas anteriores (0,8% a 2,3%). La probabilidad de recuperar una marca en una zona que no sea aquella en que se realizó el marcado parece depender de dos factores: (i) el tiempo de libertad y (ii) la edad (o la talla) de los peces; cuando el pez pasa más tiempo en libertad o alcanza una edad más avanzada, mayor es la probabilidad de que se detecte una migración trasatlántica.

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MOTS CLES

Conventional tag, migration rates, Thunnus thynnus, East and West Atlantic stocks

INTRODUCTION

In 1982, ICCAT established a line to separate the eastern and western Atlantic bluefin tuna management units on the basis of separate spawning sites (Gulf of Mexico in the West and the western Mediterranean in the East). Recently, the recovery of 40 pop-up satellite tags and 30 archival tags from bluefin released in the West Atlantic (coasts of New England) clearly indicated the occurrence of a significant (and higher than expected) percentage of migrations from West to East of the North Atlantic (i.e., 16% to 35% of the cases, Block et al. 2001, Lutcavage et al. 2001). The pop-up satellite tags from bluefin released in the East Atlantic (Southern coasts of Spain and western Mediterranean) lead to a surprisingly low return rate (0% to 50%). Therefore, the results must be interpreted with caution. During the 3 years of this program (1998 to 2000), 13 tags were successfully recovered and none of them exhibited transatlantic migrations (de Metrio et al. 2001).

ICCAT conventional tagging data have also shown that a number of fished tagged in the West have been recaptured in the East and *vice versa* (Mather et al. 1995). However, the estimated annual migration rates differ between authors. The NRC (1994) estimated the West-to-East and East-to-West migration rates around 1% and 2%, respectively; Punt and Butterworth (1995) about 4% and 1-6%, respectively; and Turner and Powers (1995) about 3-5% and 1%, respectively. More recently, Porch and Turner (1999) used an overlap and a diffusion model and found higher West-to-East mixing coefficients than East-to-West, but neither model fitted the tagging data well. Because the differences in mixing rate estimations mainly depend on modelling structure and assumptions (Porch et al. 2001), the present paper presents a simple descriptive analysis of the ICCAT bluefin tuna tagging database.

DATA

We here used the bluefin tuna tagging database (i.e., conventional tags) provided by ICCAT secretariat in July 2001. Our purpose was to determine the number and percentage of resident and transatlantic migratory tags area-by-area (we here considered the two ICCAT management units, being delimited by the 45°W), decades-by-decades (from the 50's to the 90's), by age-classes and in relation to the time at liberty. Therefore, we only retained records including dates and coordinates of both releases and recaptures. Because the database contained some errors (that should be soon corrected by ICCAT secretariat), we further cleaned it up by removing doubtful records (e.g., records including dates of release posterior to those of recovery). Finally, we kept 4979 records among the 16502 of the original database (~ 30% of the releases), except for the analysis by age-class which was based on the 4579 tags, which also provided information on length or weight at release.

RESULTS AND DISCUSSION

Since 1954 (year of the first releases), about 91.18% of the tags were released in the West Atlantic and 8.82% in the East Atlantic (Figure 1, Table 1). More than 75% of the releases in the West Atlantic were done along the US coasts between 38°N and 42°N. In the East Atlantic, about 70% were released in the Bay of Biscay and 25% along the Spanish Mediterranean coast. Rates of recaptures were about the same as those of releases (although a bit higher in the East Atlantic: 10.48% against 8.82%) and they mainly took place in the same areas (Figure 1, Table 1).

Differences between the release and recapture areas firstly reflect contrasts between the locations of release and the various fishing zones (e.g., the occurrence of recaptures along the Norwegian coast being related the Norwegian fishery and those along the West part of the Gulf Stream to the long liner fishery, Figure 1). Note that the recaptures along the Gulf Stream matched the locations of the satellite and archival tags, supporting the hypothesis of a feeding zone along the Gulf Stream. Differences

between the release and recapture areas also reflect the migrations patterns to the identified spawning sites, i.e., to the gulf of Mexico and around the Balearic islands (Figure 1).

Decades-by-decades, one may see that the tagging effort did not match between the East and the West Atlantic. In the West, 80% of the tags were released in the 60's and 70's, whereas 88% of the releases were done during the 80's and 90's in the East (Table 1, note, however, that the number of releases became of the same magnitude between the two areas during the last two decades).

Averaged times at liberty were similar between East and West Atlantic (313 and 355 days for East and West Atlantic, respectively). These values remained similar over decades in the East, but apparently not in the West (this of the 60's being much lower, Table 1). However, the boxplot indicated that the time at liberty were not significantly different between decades in the West nor in the East (only the mean or the median can be different in some cases, but not the distributions, Figure 2).

The great majority of tags was recaptured in their area of release, i.e., 95.67% and 97.75% for the East and the West Atlantic, respectively (Table 2). The number of tags released in the West and recaptured in the East (102) was about 5 times higher than the reverse (19), but the percentage of transatlantic migrations from East-to-West (4.33%) was about 2 times higher than the one from West-to-East (2.25%, Table 2). These estimates are of same magnitude as the annual migration rates estimated through different mixing models, but conversely to above-mentioned works (except the NRC's one), ICCAT tagging database indicated a higher proportion of migration from East-to-West than from West-to-East. However, these estimates of transatlantic migrations (as probably those of above-mentioned works) must be considered with caution, because of the low number of observations (19 and 102 records among 4979 ones for East-to-West and West-to-East, respectively).

The percentage of transatlantic migrations seems to vary over decades, especially from West-to-East (Table 2). It was much higher during the 90's (7.64%) than in the three previous decades (0.84% to 2.28%). Note also that among the 5 tags released in the West during the 50's, 2 were recaptured in East (Bay of Biscay, i.e., 40% of transatlantic migration). These variations would be in agreement with Tiews (1963), who hypothesised, on the basis of observations on the feeding conditions, that the remarkable change in the age composition of the German catches in 1952 and 1953 and the considerable increase in the Norwegian catches in 1961 could be related to exceptional immigration of bluefin tunas from the West Atlantic. At the light of the results displayed by the satellite tags, one could hypothesise that the Norwegian Sea and the North Sea constituted, in some years of the 50's and 60's, a natural extension of the feeding area for western bluefin tunas that fed along the Gulf Stream.

Time at liberty seems to be much lower for tags released and recaptured in the same area (289 and 342 days for the East and the West, respectively) than those released and recaptured in a different area (836 and 904 days for the East and the West, respectively, Table 2 and Figure 3-top panel). One may argue that this result is simply an artefact, because fish being recaptured within a few months had no time to cross the 45°W parallel. If this argument is valid, times at liberty for tags released and recaptured in the same area should become comparable to those of tags released but recaptured in a different area, after having removed the records displaying the lower times at liberty. Considering that the net horizontal displacement of an adult bluefin tuna is about 76 km/day (Lutcavage et al. 2000), we re-computed the boxplot considering different thresholds (> 66 days ~ > 5000 km; > 132 days ~ > 10000 km; > 198 days ~ > 15000 km and > 264 days ~ > 20000 km). Time at liberty of tags released but recaptured in a different area did not display any differences with or without thresholds (Figure 3). However, time at liberty for tags released and recaptured in the same area appeared higher after the threshold of 66 days (567 against 289 days for the East and 535 against 342 days for the West), then remained approximately constant (Figure 3). However, these values still remained lower than those of tags released but recaptured in a different area (Table 2). This would mean that the probability to get a recapture in a different area than the area of release is time-dependent; higher the time at liberty, higher the probability to get a transatlantic migration.

Because of the rather low number of transatlantic migration, we only considered 3 crude age-classes: (i) juveniles in both East and West Atlantic (fish < 35 kg or 110 cm, i.e.,< ~ 4 years old), (ii) adult in the East but juvenile in the West (35 kg or 110 cm < fish < 120 kg or 180 cm, i.e., ~ 4-8 years old) and (iii) adult in both sides (fish > 120 kg or 180 cm, i.e., > ~ 8 years old). 89.28% of the conventional tags was released on juveniles, 4.45% on 4-8 years old and 6.27% on BFT > 8 years old (Table 3). There were few spawners released in the East and being recaptured (only 7 fish of 4-8 years old). About 98% of the juveniles was recaptured in their areas of release and only 2% displayed transatlantic migration (0.43% from East-to-West and 1.59% from West-to-East). About 97.55% of the 4-8 years old was also recaptured in their areas of release and 2.45% displayed West-to-East migration. A lower percentage (92.68%) of old fish was recaptured in their areas of release and the transatlantic migration rate is notably higher (7.32%, Table 3). Among the tags displaying West-to-East migration, there is a clear positive relationship between age and transatlantic migration rate. The percentage of spawners doing transatlantic migration is more than 4 higher than the one of juveniles. This feature cannot be attributed to the time-at-liberty, which was similar between juveniles (802 days) and fish older than 8 years (891 days, Table 3, see also Figure 4). Only the 4-8 years old fish seems to display a much higher time at liberty, which could be due to a different behaviour of this age-class, but this estimate is likely to be biased because of the low number of observations (5). Finally, these results indicate that the probability to get a recapture in a different area than the area of release is age-dependent; older the fish, higher the probability to get a transatlantic migration. Note that this result would imply that the East-to-West migration rate could be underestimated, because more than 98% of releases being recaptured concern juvenile BFT.

CONCLUSION

This crude investigation of the conventional tagging database indicated:

1. The great majority of the conventional tags were released in the West Atlantic (91.18%).
2. Most of the conventional tags were recaptured in their area of release (95.67% and 97.75% for the East and the West Atlantic, respectively).
3. The percentage of transatlantic migrations from East-to-West (4.33%) was about 2 times higher than the one from West-to-East (2.25%).
4. Migration rates are likely to vary from year-to-year and/or decades-to-decades.
5. The probability to get a recapture in another area than the one of release is probably dependent on the time at liberty and the age of the fish; higher the time at liberty and/or older the fish, higher the probability to get a transatlantic migration.

Points 3, 4 and 5 gave interesting, but crude indications and must be interpreted with carefulness. These estimates are likely to be biased by different factors, such as the relatively low number of observations, the relatively low number of releases and recaptures on adults, changes in fishing activity through time and space or differences in mortality due to tagging between age-class. Note, however, that carefulness does not mean rejection. These crude estimates are also likely to capture some of the underlying processes.

Ecological and tagging information on Atlantic BFT clearly indicate that the 45°W boundary is artificial. Nonetheless, no reliable information is available to define a rational boundary (if ever exists), nor to create further sub-stocks. Regarding our present knowledge, mixing stock assessment models between West and East stocks or single North Atlantic stock model (being spatially structured) could appear a good option. However, this issue is far more complex than it firstly appears, especially if significant differences in abundance occur between the two stocks (see e.g. the discussion in Porch et al. 2001). Furthermore, the above points 4 and 5 indicate that implementing mixing in a stock assessment model also imply estimates of transatlantic migrations rates per age-class and per year (or decade).

Finally, a mixing or diffusion stock assessment model involves that catch and effort data of both the East and West stocks be trustworthy, which is not the case for the East stock (ICCAT 2001, see also the Annex). During the last stock assessment of the East stock in 1998, the working group already mentioned that their estimates were partially blurred by large uncertainties due to a lack of data and information (ICCAT 1999). Since then, our confidence in the input data further declined (ICCAT 2001, Annex), so that the quantitative stock assessment has been postponed in 2000 (which, however, does not imply that the SCRS cannot propose management measures for this stock, see e.g., Fromentin and Fonteneau 2001). Without a clear and real improvement in the East Atlantic bluefin tuna database, there is no way to expect for a trustworthy and reliable Atlantic bluefin stock assessment, including mixing between East and West Atlantic. To do so, a significant improvement in the estimates of transatlantic migrations rate is needed (for instance by tagging more fish of 4-8 years old and more adults in the East) and pressure must be put on the different fishing countries to get accurate and trustworthy catch and effort data.

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ANNEX

Most important sources of uncertainty in the East Atlantic databases probably relate to a **mis-reporting of the catches**.

- ✓ In 1998, there was a revision of the official statistics for the 1991-1997 period, which was actually motivated by the establishment of a TAC. This revision lead to an 20 to 25% increase of the total catches, demonstrating that the official statistics of the contracting parties were (or are?) inaccurate and further lead to a discrepancy in the catch-at-age matrix (data before and after 1991 being no more consistent). In 2000, the total import on the Tokyo market from the most important fisheries has been estimated to exceed the official landings of these fisheries by more than 3000 tonnes; i.e., an under-reporting of at least 10% of the total catches. These two examples clearly show that the implementation of a TAC has induced strong negative effects by increasing mis-reporting.

- ✓ During the 90's, the demand of the Japanese market has considerably increased and induced a very rapid development of the **pool and caging systems** (fish is not landed anymore, but directly transferred alive from the purse seine to a cage in order to be fattened in big pools during several months). This new system has unfortunately lead to a serious decrease in the quality of the basic statistics between 1997 and 2000. The implementation of the UE logbooks in 2001 should, however, lead to a better coverage of the total catch that goes through this system (Task I data), but won't allow to get accurate individual length or weight (Task II data).

- ✓ **Illegal fishing of age 0 and 1** is suspected to be important in several Mediterranean countries, but it is still poorly reported to ICCAT (partially because this fishing is due to the small-scale and recreational fisheries).

- ✓ Trustworthiness in the statistics of **non-contracting parties** is totally ignored.

- ✓ '**Pirate fishing boats'** lead to an important under-reporting, which is difficult to estimate.

A second and significant source of uncertainty relates to the **quantification of fishing effort**.

- ✓ Changes in gear-technology and tactics mainly affect the purse seiner fleet, which is the major one (about 50% of the total landings) and secondarily the baitboat fleet. If changes in length and power can be modelled, more difficult is to model objectively the recent and increasing use of powerful positioning and prospecting equipment, such as birds radar, sounder, sonar and plane as well as new storage equipment, such as carrier vessel with deep freezing storage and now pool system.

- ✓ The Japanese market also induced a **change in the selectivity patterns** of the purse seiner fleets, which now target the spawners during a full season and subsequently strongly expand and explore new fishing grounds.

- ✓ A last difficulty with the purse seiner fleet relates to their **fishing strategy**. Purse seiners used to work in teams of about 5 boats. When a boat caught a school, it shares its catches with his partners but also with boats of other teams if the latter arrives at the fishing location before the former could have finished to surround the school with its seine. Some teams change from year-to-year and there is a strong competition between them. These changes, which affect positively and negatively fishing effort, are very difficult to quantify (if ever possible) without a highly detailed information provided by observers.

Table 1. Number, percentage and time at liberty (in days) of releases by decade in the East Atlantic (top) and the West Atlantic (bottom).

Releases and recaptures in the East

	East rel. (number)	East rel. / all rel. (%)	Time at liberty (days)	East rec. (number)	East rec. / all rec. (%)
Total	439	**8.82%**	313 (43)	522	**10.48%**
50's	-	-	-	2	0.04%
60's	1	0.02%	684	45	0.90%
70's	51	1.02%	272 (108)	62	1.25%
80's	255	5.12%	318 (62)	248	4.98%
90's	132	2.65%	315 (65)	165	3.31%

Releases and recaptures in the West

	West rel. (number)	West rel. / all rel. (%)	Time at liberty (days)	West rec. (number)	West rec. / all rec. (%)
Total	4540	**91.18%**	355 (16)	4457	**89.52%**
50's	5	0.10%	754 (195)	3	0.06%
60's	1975	39.67%	257 (9)	1931	38.78%
70's	1661	33.36%	426 (27)	1650	33.14%
80's	428	8.60%	447 (86)	435	8.74%
90's	471	9.46%	425 (40)	438	8.80%

Table 2. Number, percentage and time at liberty (in days) considering the area of release and this of recapture.

Released and recaptures in the East

	East rel. & East rec. (number)	East rel. / East rel. (%)	Time at liberty (days)
Total	**420**	**95.67%**	289 (42)
50's	0	-	-
60's	0	-	-
70's	48	94.12%	224 (78)
80's	243	95.29%	292 (61)
90's	129	97.73%	308 (65)

Releases in the East being recaptured in the West

	East rel. & West rec. (number)	West rec. / East rel. (%)	Time at liberty (days)
Total	**19**	**4.33%**	836 (298)
50's	0	-	-
60's	1	100%	684
70's	3	5.88%	1044 (1219)
80's	12	4.71%	854 (380)
90's	3	2.27%	608 (440)

Released and recaptures in the West

	West rel. & West rec. (number)	West rec. / West rel. (%)	Time at liberty (days)
Total	**4438**	**97.75%**	342 (15)
50's	3	60%	294 (447)
60's	1930	97.72%	249 (17)
70's	1647	99.16%	421 (26)
80's	423	98.83%	418 (82)
90's	435	92.36%	387 (39)

Releases in the West being recaptured in the East

	West rel. & East rec. (number)	East rec. / West rel. (%)	Time at liberty (days)
Total	**102**	**2.25%**	904 (174)
50's	2	40%	1824 (43)
60's	45	2.28%	631 (225)
70's	14	0.84%	980 (569)
80's	5	1.17%	2891 (1194)
90's	36	7.64%	889 (154)

Table 3. Number, percentage and time at liberty (in days) of conventional tags by age-class.

Releases and recaptures by age-classes

	Total	**< 4 years old**	**4-8 years old**	**> 8 years old**
Releases (nb)	4579	4088	204	287
Releases (%)	**-**	89.28%	4.45%	6.27%
East -> East (nb)	420	413	7	0
East -> East (%)	**-**	10.10%	3.43%	-
East -> West (nb)	19	19	0	0
East -> West (%)	-	0.46%	-	-
West -> West (nb)	4049	3591	192	266
West -> West (%)	-	87.84%	94.12%	92.68%
West -> East (nb)	91	65	5	21
West -> East (%)	**-**	**1.59%**	**2.45%**	**7.32%**
West -> East (time at liberty)	878	802	1784	891

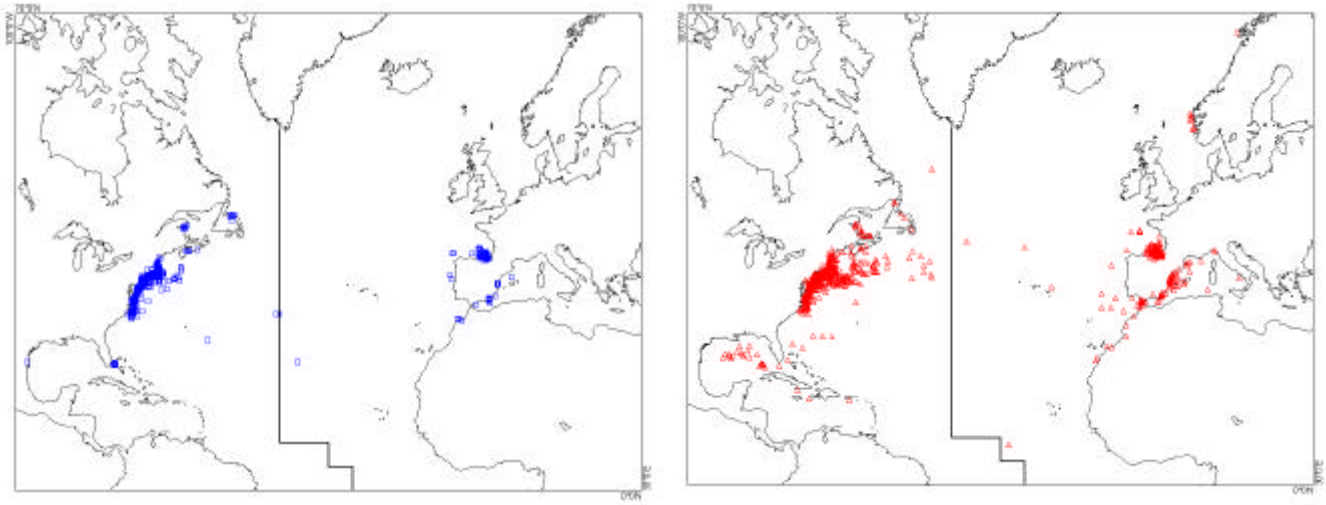

Figure 1. Map of releases (right) and recaptures (left) of the ICCAT conventional tagging database

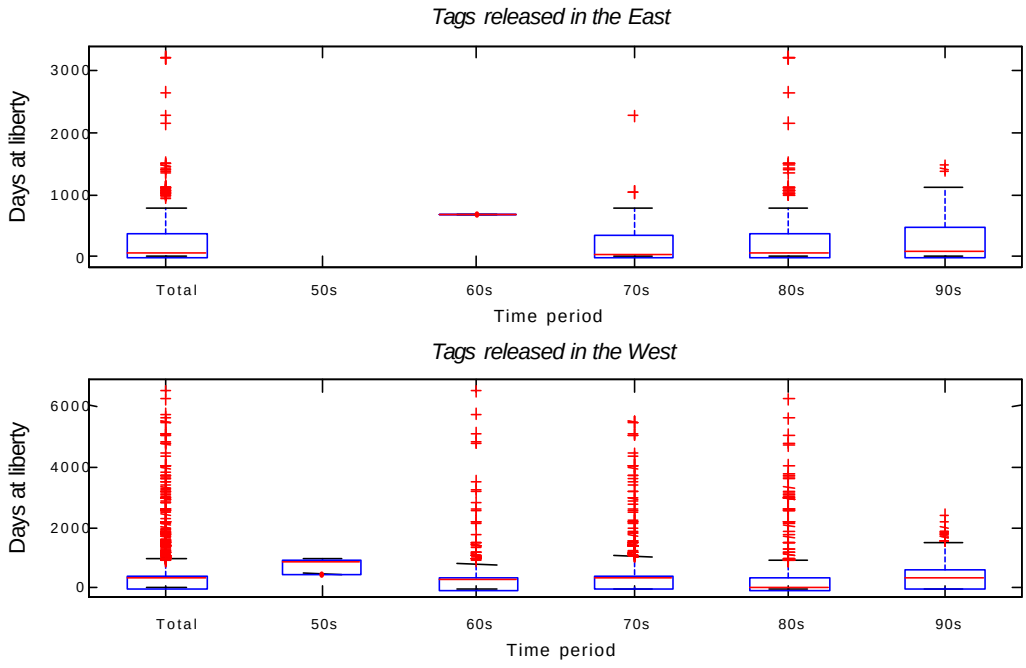

Figure 2. Boxplot of times at liberty (in days) decades-by-decades of tags being released in the East (top) and in the West (bottom) and recaptured in any area.

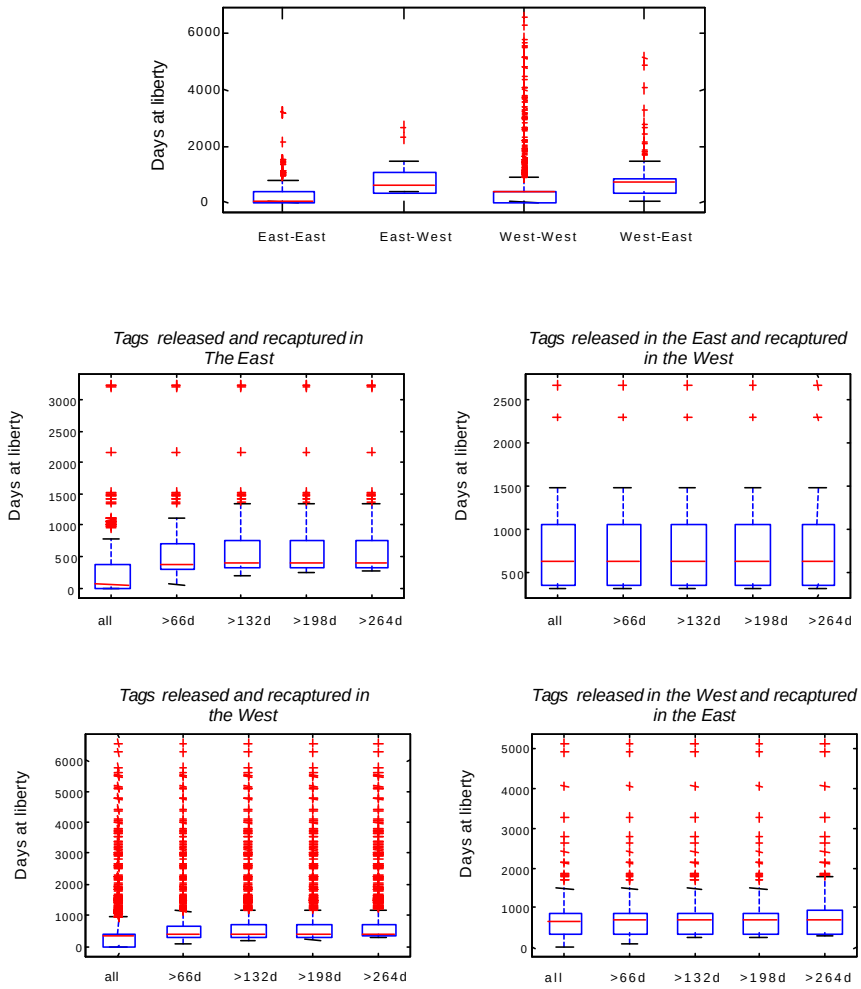

Figure 3. Boxplot of times at liberty (in days) considering the area of release and this of recapture (top). Same as top panel considering different thresholds (> 66 days ~ > 5000 km; > 132 days ~ > 10000 km; > 198 days ~ > 15000 km and > 264 days ~ > 20000 km)

Figure 4. Boxplot of the times at liberty (in days) by age-class for conventional tags being released in the West and recaptured in the East