

TAGGING BLUEFIN TUNA IN THE MEDITERRANEAN SEA: CHALLENGE OR MISSION: IMPOSSIBLE?

Jean-Marc Fromentin¹

SUMMARY

Since 2007, Ifremer together with the French Federation of Sport fishermen (FFPM) and Big Game Fishing Club France (BGFCF) have been carrying out a program of conventional and electronic tagging on bluefin tuna in the western Mediterranean Sea. 479 and 95 ICCAT "spaghetti" tags have been deployed by the FFPM recreational and sportive fishermen along the Mediterranean French coasts in 2007 and 2008, respectively. To date, not a single recapture has been registered. Ifremer together with BGFCF has deployed 11, 6 and 8 pop-up archival tags (PAT) offshore of Marseille in 2007, 2008 and 2009, respectively. Outputs were impaired by two main technical difficulties: premature detachment and low transmission rates in the Argos band over the Mediterranean. While the first difficulty can be partially solved, the second remains a key limitation when using pop-up archival tags in this area. Preliminary results are, however, of interest and indicate that (i) most tagged fish remained in the western Mediterranean Sea and did not migrate in the Atlantic but (ii), migration to the central Mediterranean Sea (Sicily or Gulf of Syrta) occurred during the spawning period, and (iii) a possible foraging ground has been detected South of the Gulf of Lions in both 2007 and 2008.

RESUME

Depuis 2007, l'Ifremer, la Fédération française des pêcheurs en mer (FFPM) et le Big Game Fishing Club France (BGFCF) joignent leur effort pour mener une campagne de marquage conventionnel et électronique sur le thon rouge de la Méditerranée occidentale. Les pêcheurs récréatifs et sportifs de la FFPM ont apposé respectivement 479 et 95 marques « spaghetti » ICCAT le long des côtes méditerranéennes françaises en 2007 et 2008. Aucune recapture n'a été répertoriée pour l'instant. L'Ifremer et le BGFCF ont déployé 11, 6 et 8 marques archives pop-up (PAT) au large de Marseille en 2007, 2008 et 2009 respectivement. Deux difficultés techniques entachent cependant les résultats : la prématurité des détachements et la médiocre performance du système Argos sur la Méditerranée. Si la première de ces difficultés peut être en partie résolue, la seconde reste une limitation clé pour l'utilisation des PAT en Méditerranée. Les résultats préliminaires sont cependant intéressants et montrent que : (i) la plupart des poissons marqués sont restés en Méditerranée occidentale et n'ont pas migré en Atlantique, mais (ii) une migration en Méditerranée centrale (Sicile et golfe de Syrte) s'est produite lors de la période de reproduction et (iii) une aire potentielle de nutrition a été identifiée au sud du Golfe du Lion en 2007 et 2008.

RESUMEN

Desde 2007, el Ifremer, la Federación francesa de Pesca marina (FFPM) y el Big Game Fishing Club Francia (BGFCF) ha estado llevando a cabo un programa de marcado convencional y electrónico de atún rojo en el Mediterráneo occidental. Los pescadores recreativos y deportivos del FFPM han colocado 479 y 95 marcas "espagueti" de ICCAT a lo largo de las costas mediterráneas francesas en 2007 y 2008, respectivamente. Hasta la fecha no se ha producido ninguna recaptura. Ifremer, junto con BGFCF, ha colocado 11, 6 y 8 marcas archivo pop-up (PAT) en aguas de Marsella en 2007, 2008 y 2009 respectivamente. Sin embargo, los resultados se han visto afectados por dos dificultades técnicas: suelta prematura y bajas tasas de transmisión en la banda Argos a lo largo del Mediterráneo. Aunque la primera dificultad puede ser parcialmente resuelta, la segunda sigue siendo una limitación importante al usar marcas archivo pop-up en esta zona. No obstante, los resultados preliminares son interesantes e indican que (i) la mayoría de los peces marcados permaneció en el Mediterráneo

¹ IFREMER, Centre de Recherche Halieutique Méditerranéen et Tropical, avenue Jean Monnet, BP 171, 34203 Sète cedex, France. E-Mail: jean.marc.fromentin@ifremer.fr

occidental y no emigró al Atlántico pero (ii) la migración al Mediterráneo central (Sicilia y golfo de Syrta) se produjo durante la temporada de puesta, y (iii) se ha detectado una posible zona de alimentación al Sur del Golfo de León tanto en 2007 como en 2008.

KEYWORDS

Thunnus thynnus, tagging, Mediterranean Sea, pop-up archival tag, conventional tag

1. Introduction

Most of the conventional tagging experiments on bluefin tuna have been carried out in the northwestern or northeastern Atlantic, but more rarely in the Mediterranean Sea (Fromentin 2002; Anon. 2002), while the great majority of electronic tags have been deployed along the western Atlantic coasts (Block *et al.* 2005; Sibert *et al.* 2006; Walli *et al.* 2009). Consequently, the tagging surveys are seriously unbalanced. This limits our ability in describing migration patterns in the Mediterranean Sea or estimating mixing rates between the Mediterranean and the North Atlantic. This point is crucial because 70% of bluefin tuna catch come from the Mediterranean Sea. Furthermore, this also partially explains why the assessment models incorporating stock mixing are so difficult to calibrate and still not reliable (Porch *et al.* 2001; Anon. 2009).

We present here the first results of the tagging surveys carried out on bluefin tuna along the Mediterranean French coasts since 2007. The French Federation of Sport fishermen (FFPM) has performed the conventional tagging experiment, while the electronic tagging survey has been carried out by Ifremer in the frame of the Data Collection Framework of DG MARE in 2006 and 2007 and under Ifremer funding since 2008. The Ifremer survey has been done in close collaboration with the Big Game Fishing Club France (BGFCF) which further purchased some electronic tags.

2. The Conventional tagging program

Following the decreasing trend in the catch rates of the French recreational and sport fishing fleet targeting bluefin tuna (Ordan 2006), the FFPM has decided to implement a conventional tagging program, with Ifremer scientific support and using ICCAT conventional tags. In 2007, 479 and 97 tags have been deployed in 2007 and 2008, respectively. In 2009, this program has continued but these results are not yet available.

The map of the release locations (**Figure 1**) showed that most of the BFT have been tagged, in 2007 and 2008, between 3° and 8° longitude East, either close by the French Mediterranean coast (at about 43.10° North) or a bit more offshore (at about 42.40° North).

Regarding the size, both the median and the mean are about 80 cm while the median of the weights is about 10 kg and the mean about 13 kg (**Figure 2**). In other words, the conventional tagging carried out by FFPM in the northwestern Mediterranean sea mostly targeted juveniles BFT, more precisely fish of ages 1 to 4 (85% of the fish are ≤ 30 kg).

Recapture rate so far is null which is disappointed with a total of release of about 576 fish in a same and rather small area (i.e., a low recapture rate of about 1% would have led to 5 to 6 recaptures).

3. The electronic tagging program

3.1 Technical limitations

Past pop-up archival surveys on different biological platforms (fish and birds) has led to suspect transmission failure in the Argos over the Mediterranean Sea. After an inquiry from Argos-France, it appeared that the Argos band is polluted by various sources of noise over the Mediterranean Sea, so that a minimum transmission power of 0.3 W is needed (Argos Comm. Pers). Therefore, we only deployed Wildlife Mk10 pop-up archival tags (PAT) which display a transmission power of about 0.5 W.

All the deployments were performed with Daniel Lopuszanski, a trained sport fisherman from BGFCF who places his boat at disposal. The fish is caught by roll and reel and put on board for tagging operation (which lasts one to two minutes). We double tagged to maintain the tag along the body of the fish. In 2007 and 2008, tags were deployed on 12 medium-size fish (i.e. young spawners from 124 to 144 cm) to 5 large-size fish (188 to 235 cm, **Table 1**). 5 additional PAT should be deployed by the end of 2009 while 13 other PAT should be deployed in 2010.

All the tags have popped-off, except tag 68407 which has been recaptured by recreational fishermen offshore the Algerian coast in January 2008 (i.e. 73 days after deployment, **Table 1**). Although preliminary contacts with the fishermen, we could not recover this tag and the information is unfortunately lost.

All the tags were programmed to detach 12 months after release and have thus detached prematurely. Premature detachment is supposed to be due to: the anchorage of the umbrella dart, the high activity of medium size fish, possible weakness in the pin of the tag or to (illegal) fishing. In 2008, the anchorage of that dart was placed into the pterygiophores (instead of the dorsal muscle). This led to substantial improvements and to the two longest times-at-liberty, respectively 170 and 240 days (**Table 1**). The place of anchorage is thus of key importance but does not fully explain all the premature detachments. Fishing is also a reason and explained the premature detachment of at least one tag among the 17 tags (i.e. tag 68407, see above). Tag failure, especially of the pin, has been also advocated but is difficult to check and/or confirm. One fish seems to have died because of tagging, i.e. fish 37333 which sank in deep waters four days after tagging.

A more serious difficulty relates to the quality of the Argos transmission over the Mediterranean Sea. When popping-off, the tags have emitted 7 to 16 days (mean = 10.9 +/- 1.3 days). However, the number of clear messages varied considerably among tags, i.e. from 17 to 528 (**Table 1**). Furthermore, the number of corrupted messages was always very large, reaching 58% of the total number of message in average (**Table 1**). This problem strongly affects both the quantity and the quality of the data being transmitted. Indeed, if the number of transmission days (i.e., the number of days during which the tags transmit information to the satellite) is not related to the total of number of messages being transmitted (**Figure 3a**), the latter is clearly and positively related to the number of days with information: greater the number of messages, greater the number of days with light or temperature or depth information (**Figure 3b**). In average, the tags remained 82 days at sea, but only 31% of these days include either information on light, or temperature or depth (**Table 1**). In other words, 69% of days at sea are without information but this ratio varied, again, a lot among tags. For instance, the longest track (tag 87642) only displayed information on light, temperature or depth for 16 days among the 240 days at liberty (i.e. ~7%), while tag 87641 displayed information for 55 days among the 62 days at liberty (i.e. 89%, **Table 1, Figure 3c**).

Actually, **Figure 3c** displays a negative relationship which is confirmed when plotting the total number of messages against the number of days-at-sea (**Figure 3d**). In other words, the longer the track, the lower the number of days with information. However, it seems that the number of days with information cannot exceed 50 days whatever the number of days-at-sea (that can reach 240 days), while it should increase proportionally (i.e. along the broken line of **Figure 3e**). Finally, it may possible that the number of messages that can be transmitted through Argos over the Mediterranean is limited (i.e. cannot exceed a given threshold) and furthermore be season-dependent (**Figure 3f**): late August to December being the most favorable period.

3.2 Preliminary results

All the data have been processed similarly, using the Wildlife software and the particule filter developed by Royer *et al.* (2005; 2009). The results have to be seen as preliminary because they are obtained on a rather restricted number of tags (16) and days at sea (1397). Nonetheless, they gave interesting indications.

All the fish moved away from the Gulf of Lions just after release but they remained in the northwestern Mediterranean a few months after tagging (i.e., in the following autumn and winter, **Figure 4**). However, the longest tracks tend to display migrations to the central Mediterranean. Tag 68409 deployed on a medium size fish tagged in autumn 2007 popped-off along the northern Tunisian coasts in February 2008. More interesting, the two tags that popped off in spring showed clear migrations to known spawning grounds: tag 87642 popped-off in the Gulf of Syrta in June 2009, while tag 80082 (deployed on a medium size fish) popped-off in the Tyrrhenian Sea (North of Sicily) in late April 2009. Unfortunately, the low number of days with information of these long tracks (**Table 1**) led to rather straightforward migration patterns that do not allow us to locate more precisely the spawning locations. None of the 16 tagged BFT displayed migration to the North Atlantic (**Figure 4**).

The kriging of the 16 tracks displays an interesting and original result: the occurrence of a possible hotspot South of Marseille (offshore the Gulf of Lions, **Figure 5**), possibly related to foraging. This hotspot that has been detected in 2007 as well as in 2008 could be an overwintering area.

The depth profiles displayed high similarities among year, fish size and seasons. They confirm that BFT mostly inhabit the surface oceanic waters (i.e. spending 50% and more than 90% of its time in 0-20m and 0-100m depth classes, respectively, **Figure 6**). The temperature profiles were more variable. Actually, differences among year and classes result from variations among seasons and the unbalanced sample design (i.e. the fact that information in summer and spring were only available in a few tags deployed in 2008). From December to March, the northwestern Mediterranean Sea displayed rather homogeneous temperatures, both on the horizontal and vertical, at around 13°C. This (together with the limited amount of data in April and May) explains the narrow range of the BFT profiles in winter and spring (**Figure 6**). More interesting are the summer and autumn profiles which indicate that BFT were preferentially in the warm waters, i.e. mostly between 18°C and 27°C temperature ranges (**Figure 6**).

4. Discussion and conclusion

Tagging bluefin tuna in the Mediterranean Sea is thus highly challenging but not Mission: Impossible. Nonetheless, scientists have to face two additional difficulties (to an already rather long list): (i) very low recapture rates and (ii) failures in the Argos transmission.

Very low recapture rates are common in most tagging programs on bluefin tuna and swordfish in the Mediterranean Sea. Usually, the recapture is most often at around 1% while it often reaches 5% to 10% in the Northeast Atlantic and up to 20% in the northwest Atlantic. This problem seems to affect the large pelagics fish in general. During the 1980s, Ifremer has carried out large conventional tagging program on albacore in the northwest Mediterranean Sea and recapture rate was about the same low level. More recently, Greek scientists have deployed 183, 158 and 39 conventional “spaghetti-type” tags on Mediterranean swordfish (in the Aegean Sea) in 2005, 2006 and 2007, respectively. An advertising campaign to fishers and harbor authorities, through posters, T-shirts, circulars was realized and every reported recapture was awarded. However, only 4 recaptures were registered by the end of 2008, i.e. a recapture rate of 1% (PGTT 2008). And this list is unfortunately not exhaustive, results from a recent Italian tagging survey on Mediterranean swordfish led to 0 recapture by the end of 2008, while 278 conventional tags have been deployed in 2005 and 2006 (PGTT 2008).

The reasons for such low recapture rates are difficult to identify, but the nature of the Mediterranean fisheries is obviously a serious candidate. These, indeed, consist of a very large number of small commercial and recreational boats operating primarily in International waters (EEZ being limited to 12 nm most of the countries). The Mediterranean area is furthermore highly diversified (fragmented) from an economical, political, administrative and cultural viewpoint which makes coordinated actions more difficult. Advertising is a key element of the success of a tagging program and scientists often pay too little attention to it. However, the very low recapture rate of the Greek program on swordfish demonstrates that if advertising is absolutely necessary, it is not sufficient to ensure reasonable recapture rates in the Mediterranean Sea. Finally, this low recapture rate also strongly limits the possibility of deploying archival tags in the Mediterranean.

Argos transmission over the Mediterranean Sea is much more limited than in other areas, such as the Atlantic or the Pacific. For instance, the average number of clear messages transmitted by a PAT in the Atlantic is about three to four times this of the same PAT in the Mediterranean Sea (CLS pers. comm.). Consequently, both the quantity and quality of information is severely reduced which impairs our ability to reconstruct the tracks (whatever the model) and thus to identify precisely spawning and foraging areas or to estimate mixing rates between areas. The origins of Argos transmission problems in the Mediterranean have been a bit investigated by Argos France. Two jamming stations have been detected North and South of the Western Mediterranean Sea, but stopping them may be difficult and they do not seem the only causes of Argos failures in the area. This issue thus remains open and one may question the possibility for alternative transmission system, such as the cell phone network developed by St. Andrews University.

Preliminary results indicate that (i) most tagged fish remained in the Western Mediterranean Sea and did not migrate in the Atlantic but (ii), migration to the Central Mediterranean Sea (Sicily or Gulf of Syrta) occurred during the spawning period, and (iii) a possible foraging ground has been detected south of the Gulf of Lions in both 2007 and 2008. These results thus tend to confirm a higher residency time in the Mediterranean than suspected, as this has been already deduced from past Italian PAT surveys (de Metrio *et al.* 2002; de Metrio *et*

al. 2004). However, carefulness is needed because of the low number of PAT deployed in the Mediterranean and rather short time-et-liberty, i.e. 82 days in average with a maximum of 240 days for the present survey.

It would be thus of great interest to maintain tagging effort on bluefin tuna in the Mediterranean for stock assessment (e.g. mixing rates) and management (e.g. time/area closure) purposes. The accumulation of data will help in identifying key habitats, main migration patterns and residency times in the Mediterranean Sea while taking into account for temporal variations. However, this can hardly be achieved without (partially) solving the above two key limitations: (i) the low recapture rate and (ii) the failures in the Argos transmission.

Acknowledgments

The French electronic tagging survey would have not been possible without Daniel's Lopuszanski indestructible fervour and key logistic support. I also warmly thank Marcel Prot and Michel Marchandise from BGFCF for their enthusiasm and contribution as well as Marcel Ordan and Jacques Champoléon from FFPM for their willingness to carry out a conventional tagging program.

References

- Anon. 2002, ICCAT Workshop on Bluefin Tuna Mixing (Madrid, Spain, September 3-7, 2001). Collect. Vol. Sci. Pap. ICCAT, 54(2): 261-352.
- Anon. 2009, Report of the 2008 Atlantic Bluefin Tuna Stock Assessment Session (Madrid, Spain, June 23 to July 4, 2008). Collect. Vol. Sci. Pap. ICCAT, 64(1): 1-352.
- Block, B.A., Teo, S.L.H., Walli, A., *et al.* 2005, Electronic tagging and population structure of Atlantic bluefin tuna. *Nature* 434, 1121-1127.
- de Metrio, G., Arnold, G.P., Block, B.A., de la Serna, J.M. Deflorio, M. Cataldo, M., Yannopoulos, C., Megalofonou, P. Beemer, S, Farwell, C. Seitz, A. 2002, Behaviour of post-spawning Atlantic bluefin tuna tagged with pop-up satellite tags in the Mediterranean and eastern Atlantic. Collect. Vol. Sci. Pap. ICCAT, 54(2): 415-424.
- de Metrio, G., Oray, I.K., Arnold, G.P., Lutcavage, M., Deflorio, M., Cort, J.L., Karkulak, S., Anbar, N. Ultanur, M. 2004, Joint Turkish-Italian research in the eastern Mediterranean: Bluefin tuna tagging with pop-up satellite tags. Collect. Vol. Sci. Pap. ICCAT, 56(3): 1163-1197.
- Fromentin, J.-M. 2002, Descriptive analysis of the ICCAT bluefin tuna tagging database. Collect. Vol. Sci. Pap. ICCAT, 54(2): 353-362.
- Ordan, M. 2006, Bluefin tuna (*Thunnus thynnus*) gros géniteurs de plus de 100 kilos. Collect. Vol. Sci. Pap. ICCAT, 59, 843-850.
- PGTT 2008, Report of the fourth and final meeting of the Planning Group on Tuna Tagging (PGTT) in the Atlantic and Mediterranean Sea. 44 pp.
- Porch, C.E., Turner, S.C., Powers, J.E. 2001, Virtual population analyses of Atlantic bluefin tuna with alternative models of transatlantic migration: 1970-1997. Collect. Vol. Sci. Pap. ICCAT, 52(3): 1022-1045.
- Royer, F., Fromentin, J.-M., Gaspar, P. 2005, A state/space model to derive bluefin tuna movement and habitat from archival tags. *Oikos* 109, 473-484.
- Royer, F., Wilson, S., Lutcavage, M. 2009, Spatial dynamics of Atlantic bluefin tuna in the North-Western Atlantic: Seasonal distribution, depth behavior and effect of the Gulf Stream variability. *Marine Ecology Progress Series. In press.*

Sibert, J.R., Lutcavage, M.E., Nielsen, A., Brill, R.W., Wilson, S.G. 2006, Interannual variation in large-scale movement of Atlantic bluefin tuna (*Thunnus thynnus*) determined from pop-up satellite archival tags. *Canadian Journal of Fisheries and Aquatic Science* 63, 2154-2166.

Walli, A., Teo, S.L.H., Boustany, A., *et al.* 2009, Seasonal movements, aggregations and diving behavior of Atlantic bluefin tuna (*Thunnus thynnus*) revealed with archival tags. *PLoS ONE* 4, e6151.

Table 1. Summary table of release and pop-off of the 17 MK-10 being deployed in 2007 and 2008.

Tag Id	Release date	Size (cm)	Pop-off date	Days-at-sea	Days with information	Clear messages	Corrupted messages	Corrupted/total
68405	21/09/07	127	21/12/07	92	34	110	167	60%
68408	22/09/07	132	26/12/07	96	9	17	72	81%
68409	22/09/07	127	11/02/08	143	23	53	123	70%
68402	24/09/07	124	11/10/07	18	15	87	241	73%
68404	24/09/07	128	25/11/07	63	45	215	260	55%
68406	24/09/07	128	27/01/08	126	21	57	103	64%
68403	03/10/07	235	13/01/08	73	-	-	-	-
68407	02/11/07	130	15/11/07	44	33	171	330	66%
37332	03/11/07	128	16/11/07	14	14	80	138	63%
37333	03/11/07	133	14/11/07	12	12	54	167	76%
37334	03/11/07	130	01/03/08	120	9	49	104	68%
37331	31/07/08	225	22/08/08	23	19	245	287	54%
87641	21/08/08	228	07/11/08	79	63	350	393	53%
87644	21/08/08	188	11/09/08	22	22	528	410	44%
87642	26/10/08	210	22/06/09	240	16	49	123	72%
87643	26/10/08	143	27/12/08	62	55	395	394	50%
80082	08/11/08	144	26/04/09	170	33	107	193	64%
Mean		156		82	26	160	219	58%

Days-at-sea: Time at liberty in number of days.

Days with information: Number of days for which light or depth or temperature information is available.

Clear messages: Number of clear (complete) messages sent by the tag through the Argos system.

Corrupted messages: Number of corrupted (incomplete) messages sent by the tag through the Argos system.

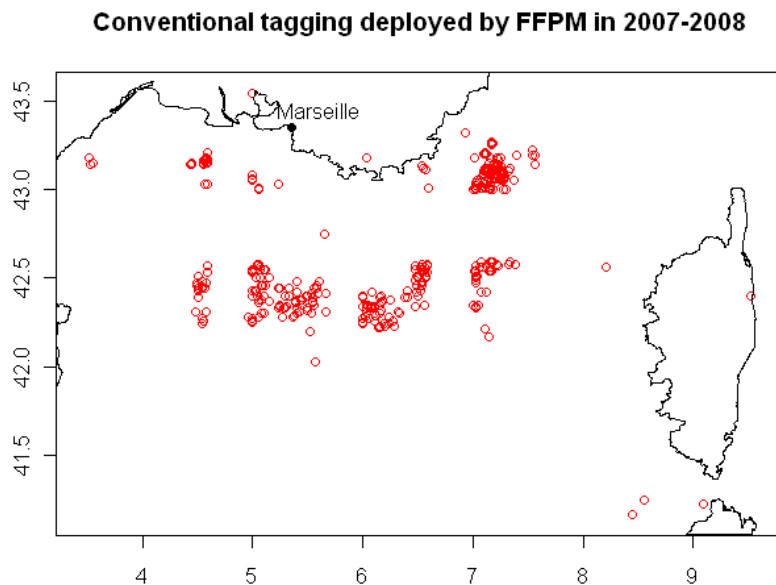


Figure 1. Map of the release locations of the FFPM conventional tagging survey in 2007 and 2008.

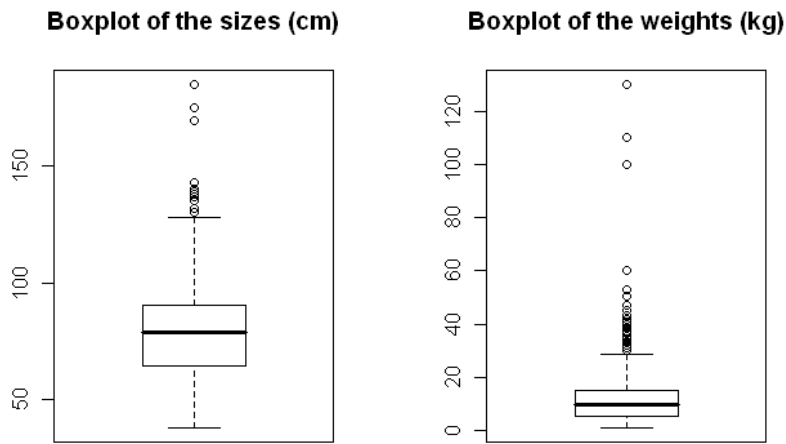


Figure 2. Box plots of size and weight of the tagged fish

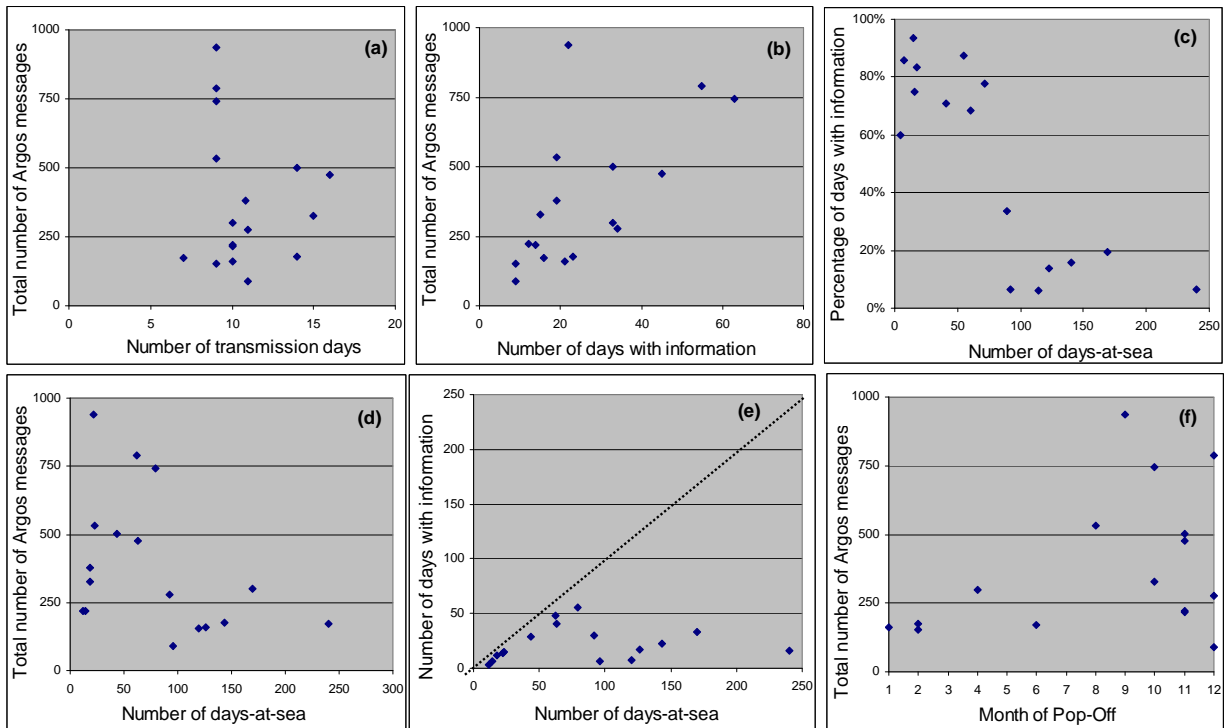


Figure 3. Summary plots of the quality and quantity of the Argos transmission.

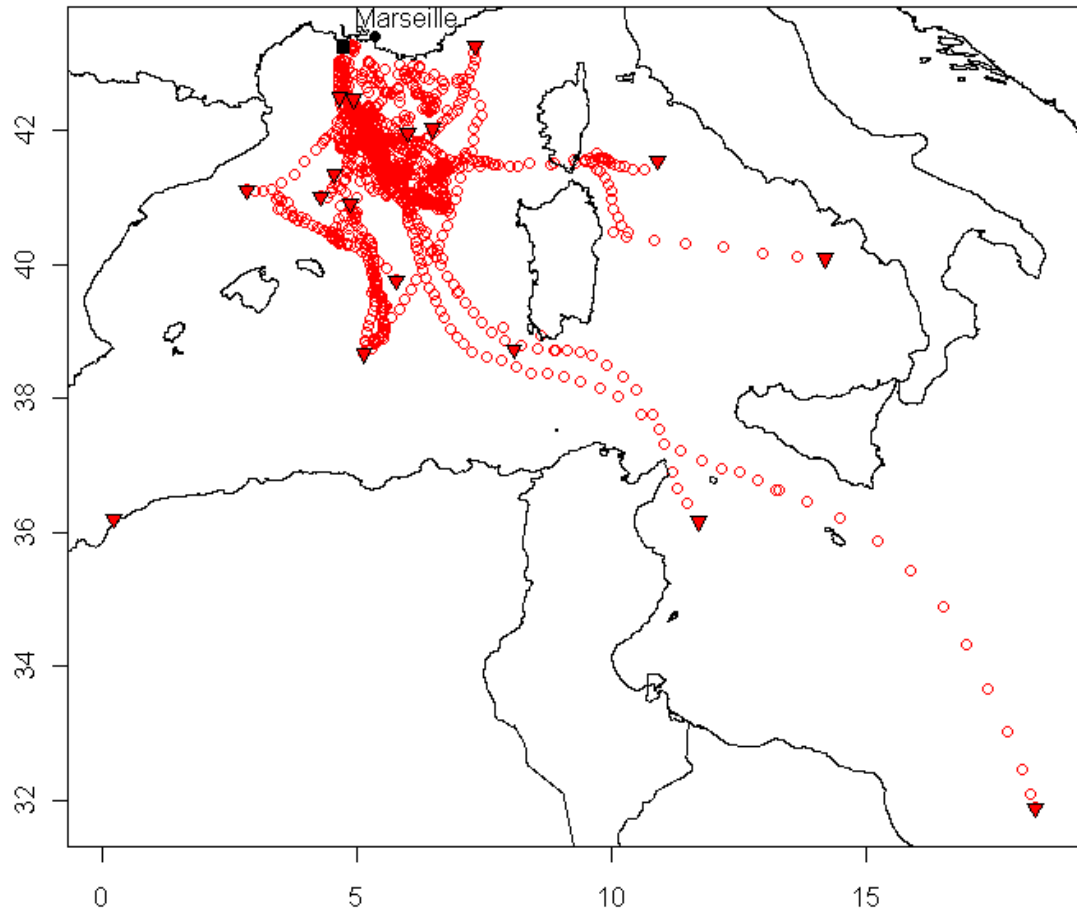


Figure 4. Processed tracks from the 17 PAT deployed on bluefin tuna by Ifremer in 2007 and 2008. Black square is the location of tagging and release. Red triangles point down with black contour are locations of pop-off.

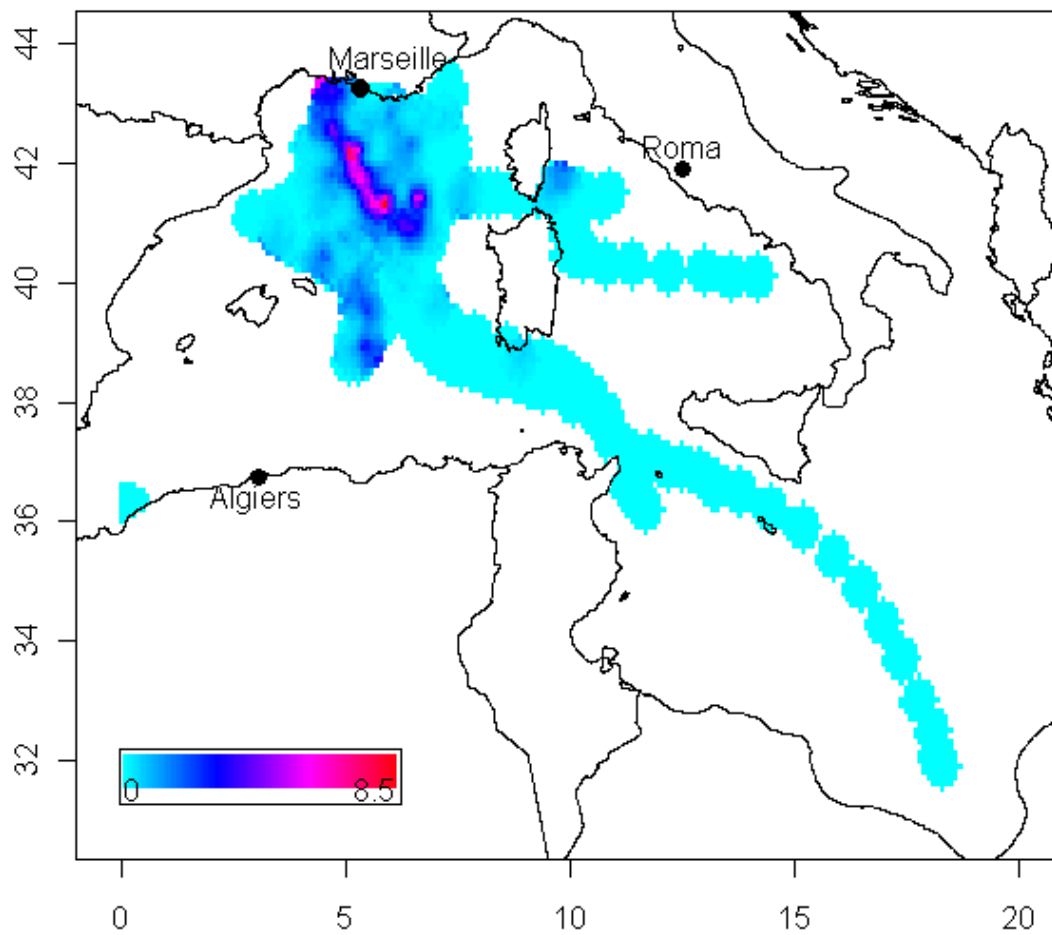


Figure 5. Corresponding map of BFT spatial occurrence obtained after kriging.

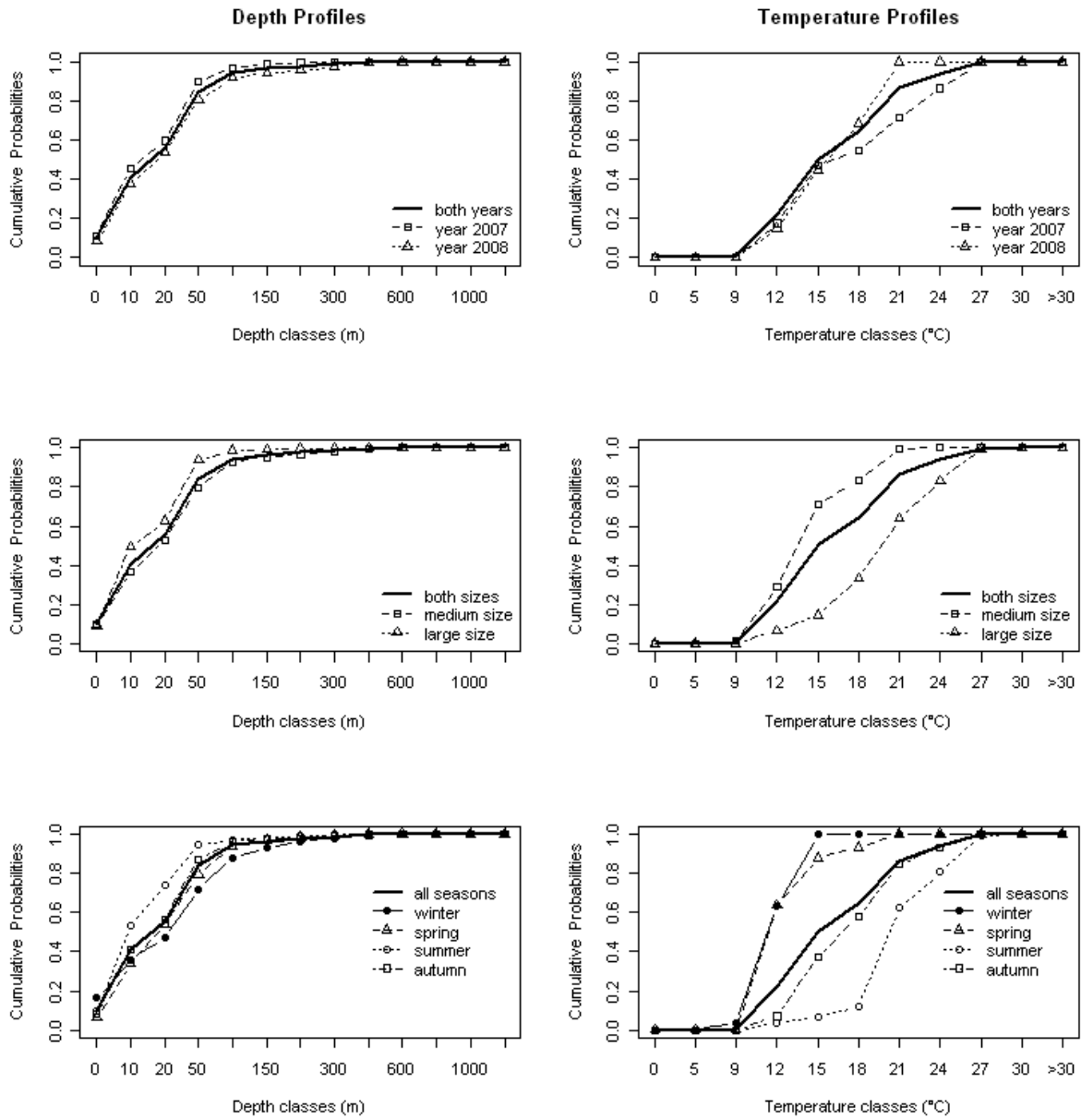


Figure 6. Cumulative probability plots for depth (left panel) and temperature (right panel).