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UPDATE OF THE FRENCH AERIAL SURVEY INDEX OF ABUNDANCE FOR 2021

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SUMMARY

The French aerial survey over the Gulf of Lions provides an important fisheries independent index for the stock assessment of Eastern Atlantic Bluefin Tuna (EABFT, Thunnus thynnus*). The present manuscript reminds the methodology employed for the survey and provides the update of the index for the year 2021 that displays a slight decrease compared to 2020, which was the highest year to date, but remains the 3rd highest value thus confirming the upward trend of the recent years.*

RÉSUMÉ

La prospection aérienne française dans le golfe du Lion fournit un important indice indépendant des pêcheries pour l'évaluation du stock de thon rouge de l'Atlantique Est (EABFT, Thunnus thynnus). *Le présent document rappelle la méthodologie employée pour réaliser la prospection et fournit la mise à jour de l'indice pour l'année 2021 qui affiche une légère baisse par rapport à 2020, qui était l'année la plus élevée à ce jour, mais reste la troisième valeur la plus élevée, confirmant ainsi la tendance à la hausse de ces dernières années.*

RESUMEN

La prospección aérea francesa en el golfo de León proporciona un importante índice independiente de la pesquería para la evaluación del stock de atún rojo del Atlántico este (*EABFT*, Thunnus thynnus). *El presente documento recuerda la metodología empleada para la prospección y proporciona la actualización del índice para el año 2021, que muestra un ligero descenso respecto a 2020, que fue el año con el valor más elevado hasta la fecha, pero ocupa el tercer puesto en cuanto al valor más alto. Lo que confirma la tendencia al alza de los últimos años.*

KEYWORDS

Juvenile Atlantic bluefin tuna; Northwest Mediterranean;
Fisheries independent abundance index; Aerial survey

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1. Introduction

The French aerial survey index has been integrated for the first time in the base case VPA of the Eastern Atlantic bluefin tuna (EABFT, *Thunnus thynnus*) stock assessment in 2017. This index is important for the stock assessment. It is one of the two fisheries-independent index included in the stock assessment. The index started in 2000 and has been updated yearly since then, with the exception of 2004-2008. It also covers young fishes from the northeast Mediterranean Sea, for which information is scarce, particularly since the enforcement of the recovery plan limiting the catch of fish below 30kg. Therefore, even if the geographical coverage of juvenile areas is not complete as it only covers the Gulf of Lions (GoL), it provides insights into stock dynamics that cannot be captured by indices covering adults. This index is currently integrated within the Management Strategy Evaluation (MSE) process developed within ICCAT. Indices used for stock assessment and part of the MSE process should be updated yearly to be made available to the SCRS Bluefin species group. The present document provides the update for the year 2021. As the index has been splitted (for the 2017 assessment) between an early period (2000-2003 FR_AER1) and a more recent period (2009-ongoing, FR_AER2), this document only presents the values for FR_AER2.

2. Materials and method

2.1 Reminder of the French aerial survey protocol

The protocol of the French aerial surveys has been described in details into several papers (Fromentin *et al.*, 2003; Bonhommeau *et al.*, 2010; Bauer *et al.*, 2015; Rouyer *et al.*, 2018; Rouyer *et al.*, 2019). Other revisions and perspectives for improvements have been presented in 2021 (Rouyer *et al.*, 2021a). The methodology is just provided here as a reminder. Aerial surveys have been carried out since 2000, excepted in 2004-2008 due to a lack of funding. The survey takes place from early-August to mid-October over the Northwestern Mediterranean Sea, in the Gulf of Lions. This period and location is favorable to school detections as EABFT are at the surface in relation to feeding and/or foraging activity.

Depending on weather conditions, up to 20 flights per year were conducted onboard a Cessna C skymaster 337 “push pull” aircraft at 1000 feet above sea level. One pilot and up to three scientists could embark on this aircraft. From 2012 to 2013 a larger plane, a Cessna Caravan 208 ISR, allowed for an IT and video specialist as well as two scientists. Greater flight times were possible, enabling to fly over the whole Gulf of Lions within one day against two with the Cessna skymaster 337. The plane was flying higher, 1500ft, and a high resolution, gyro-stabilized video-camera allowed to record the flight and to obtain accurate geolocation and images for specific school detections.

The aerial surveys take place around noon when the sun is at its highest to limit sun reflection on the sea for better detection conditions for the observers. To obtain optimal spotting conditions, flights are constrained to specific weather, sunny sky and low wind speed (<10nm/h), to avoid confusion between schools and whitecaps. Four different routes were defined for the surveys (Fig. 1), which were comparable in length 667, 648, 580, and 700 km for route 1-4 respectively. The inter-transect distance of 13.8 km reduces chances of double counting schools on subsequent transect line. The aircraft flies at the constant speed of about 200 km/h and these routes can be then flown in less than 5 hours including distance between airport and transect. Initially, for each flight, the route was randomly selected. However, practical constraints such as weather conditions often interfer in that process. The transect sections with unsuitable conditions (clouds and/or breaking waves) were skipped. When the route could not be selected randomly, special attention was paid to maximizing the spatial coverage of the area and to evening out the amount of times the different routes were flown.

Tuna schools were spotted by 1 to 3 trained scientific observers, from both sides of the plane/transects. While these teams changed over time, an overlapping period always allowed for the new members of the team to get appropriately trained to ensure the standardization of school types attribution. A GPS was used to record the position of the plane and detected tuna schools. Each detected school was then attributed to a type “tiny”, “small”, “medium”, “large” or “aggregation” for high concentrations of schools. The spotting conditions such as the wind strength (beaufort scale) and the number of observers onboard were recorded. During the early years, when the density of school was low, perpendicular distances from the plane were initially estimated by taking the GPS position of the school location. However, as the density of schools detected increased over time, it became impossible for the plane to move above the location of each school to take its GPS position. Therefore distances estimates were then realized using marks on the arms supporting the wings, which were set-up to represent pre-defined ground distances (200, 400, 800, 1200, 1800 and 3600m) at the altitude of 300m.

2.2 Density estimate

The analysis of the aerial survey data was based on the distance sampling theory (Buckland *et al.*, 2005; Thomas *et al.*, 2006). In the distance sampling theory the transects, here the routes, are defined within a given area, here the Gulf of Lions. The object of interest, here a tuna school, is recorded along the route, which is surveyed several times during a given period. The theory allows that some, perhaps many, of the objects remain undetected and that variation in detection due to environment or observer could occur, as soon as n, L and w are accurately measured. According to the line transect theory, w is estimated through a detection function, which is a model fitted to the histogram of the perpendicular distances of the detections.

The line transect approach aims to estimate the detection probability per distance (detectability P) and thus to calculate the percentage of sighted and non-sighted objects. The density estimate is given by:

$$\widehat{D_i} = \frac{n_i}{2wLP}$$

The detectability P, also known as observability or sightability, is obtained by fitting a 'detection function' to the histogram of distances. It allows to account for other variables, such as school type or environmental conditions (e.g. wind). Here it accounts for wind, the size class of schools, the number of observers onboard and the month. The shape of the detection function generally is a monotonically decreasing curve, showing a shoulder under which detection remains almost certain and is unaffected by other variables.

The mean density, $\overline{D}$, from r replicates is estimated as follows:

$$\overline{D} = \frac{1}{r}\sum_{i=1}^{i=r} \widehat{D_i}$$

The variance between replicates is estimated as:

$$Var(D) = \frac{1}{r(r-1)}\sum_{i=1}^{i=n} (\widehat{D_i} - \overline{D})^2$$

Time series of densities were computed for each model using an Horvitz-Thomson-like estimator, implemented in the R package *Distance* (Miller *et al.*, 2017).

3. Results

3.1 Update of the index

The update through to 2021 of the french aerial survey index displayed a slight decrease in 2021 compared to 2020 (Fig. 2). The 2021 density is still the third highest to date, confirming an increasing trend over the time series and consistent with the variability observed in the past.

4. Discussion

Environmental conditions are known to affect the spatial distribution of bluefin tuna in the GoL, through foraging in relationship to frontal structures and mixed layer depth (Royer *et al.*, 2005). This can translate into changes in the horizontal and vertical behavior of EABFT in the GoL, affecting its detectability and availability to the survey (Bauer *et al.*, 2017). Such effects could be accounted for in the index of abundance, using suitable habitat approaches to derive the probability of occurrence in the survey area and at the surface, depending on environmental conditions (Druon *et al.*, 2011, 2016). Changes in the environment were also identified as potential candidates affecting the presence of bluefin tuna in the Gulf of Lions (Rouyer *et al.*, 2020) and recent work confirmed this hypothesis (Rouyer *et al.*, 2021b). Using fishery data and the aerial survey data, Rouyer etal. (2021b) showed that Bluefin tuna availability is driven by northern wind events during the post-spawning period in July. The stronger these events, the higher the availability of fish in the Gulf of Lions. The yearly fluctuations in the aerial survey data appeared to be associated with these events. Such a process has therefore a direct impact on the index as years with stronger northern winds in July will increase the proportion of the bluefin tuna population susceptible to the survey. Preliminary work has been presented in previous ICCAT meetings and will lead to a revision of the index methodology in the years to come (Rouyer *et al.*, 2021a).

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References

Bauer, R. K., Bonhommeau, S., Brisset, B., and Fromentin, J. 2015. Aerial surveys to monitor bluefin tuna abundance and track efficiency of management measures. Marine Ecology Progress Series, 534: 221–234.

Bauer, R. K., Fromentin, J.-M., Demarcq, H., and Bonhommeau, S. 2017. Habitat use, vertical and horizontal behaviour of Atlantic bluefin tuna (*Thunnus thynnus*) in the Northwestern Mediterranean Sea in relation to oceanographic conditions. Deep Sea Research Part II: Topical Studies in Oceanography, 141: 248–261.

Bonhommeau, S., Farrugio, H., Poisson, F., and Fromentin, J.-M. 2010. Aerial surveys of bluefin tuna in the Western Mediterranean Sea: retrospective, prospective, perspective. Collective Volume of Scientific Papers, 65: 801–811.

Buckland, S. T., Anderson, D. R., Burnham, K. P., and Laake, J. L. 2005. Distance Sampling. In Encyclopedia of Biostatistics. John Wiley & Sons, Ltd. http://onlinelibrary.wiley.com/doi/10.1002/0470011815.b2a16019/abstract (Accessed 1 March 2016).

Druon, J., Fromentin, J., Aulanier, F., and Heikkonen, J. 2011. Potential feeding and spawning habitats of Atlantic bluefin tuna in the Mediterranean Sea. Marine Ecology Progress Series, 439: 223–240.

Druon, J.-N., Fromentin, J.-M., Hanke, A. R., Arrizabalaga, H., Damalas, D., Tičina, V., Quílez-Badia, G., *et al.* 2016. Habitat suitability of the Atlantic bluefin tuna by size class: An ecological niche approach. Progress in Oceanography, 142: 30–46.

Fromentin, J.-M., Farrugio, H., Deflorio, M., and De Metrio, G. 2003. Preliminary results of aerial surveys of bluefin tuna in the western Mediterranean Sea. Collective Volume of Scientific Papers, 55: 1019–1027.

Miller, D. L., Rexstad, E., Thomas, L., Marshall, L., and Laake, J. 2017. Distance Sampling in R. bioRxiv: 063891.

Rouyer, T., Brisset, B., Bonhommeau, S., and Fromentin, J.-M. 2018. Update of the abundance index for juvenile fish derived from aerial surveys of bluefin tuna in the western Mediterranean Sea. Collective volume of scientific papers ICCAT, 74: 2887–2902.

Rouyer, T., Brisset, B., Tremblay, Y., and Fromentin, J.-M. 2019. Update of the French aerial survey index of abundance and first attempt at integrating Bluefin tuna school size estimates from video cameras. Collective volume of scientific papers ICCAT, 75.

T. Rouyer, B. Brisset and J.-M. Fromentin. 2020. Update of the French aerial survey index of abundance for 2018. ICCAT, Collect. Vol. Sci. Pap. ICCAT. 76(2):395-400.

Rouyer, T., Bal, G., Derridj, O., and Fromentin, J.-M. 2021a. Update of the French aerial abundance index for 2020 and first attempt at accounting for the environmental effects on Bluefin tuna availability in the Gulf of Lions. Collective volume of scientific papers ICCAT, 78(3): 170-180 (2021)

T. Rouyer, S. Bonhommeau, G. Bal, O. Derridj and J.-M. Fromentin. 2021b. The environment drives Atlantic bluefin tuna availability in the Gulf of Lions. Fisheries Oceanography. https://doi.org/10.1111/fog.12532

Royer, F., Fromentin, J.-M., Farrugio, H., and Gaspar, P. 2005. Determining bluefin tuna habitat through frontal features in the Mediterranean Sea. Col. Vol. Sci. Pap. ICCAT, 58: 1275–1284.

Thomas, L., Buckland, S. T., Burnham, K. P., Anderson, D. R., Laake, J. L., Borchers, D. L., and Strindberg, S. 2006. Distance Sampling. In Encyclopedia of Environmetrics. John Wiley & Sons, Ltd. http://onlinelibrary.wiley.com/doi/10.1002/9780470057339.vad033.pub2/abstract (Accessed 1 March 2016).

Table 1. Index and CV for the index.

Year	Index	CV
2009	0.02	0.35
2010	0.01	0.53
2011	0.03	0.25
2012	0.02	0.27
2013	NA	NA
2014	0.06	0.27
2015	0.03	0.24
2016	0.11	0.20
2017	0.07	0.25
2018	0.03	0.17
2019	0.06	0.14
2020	0.14	0.15
2021	0.10	0.14

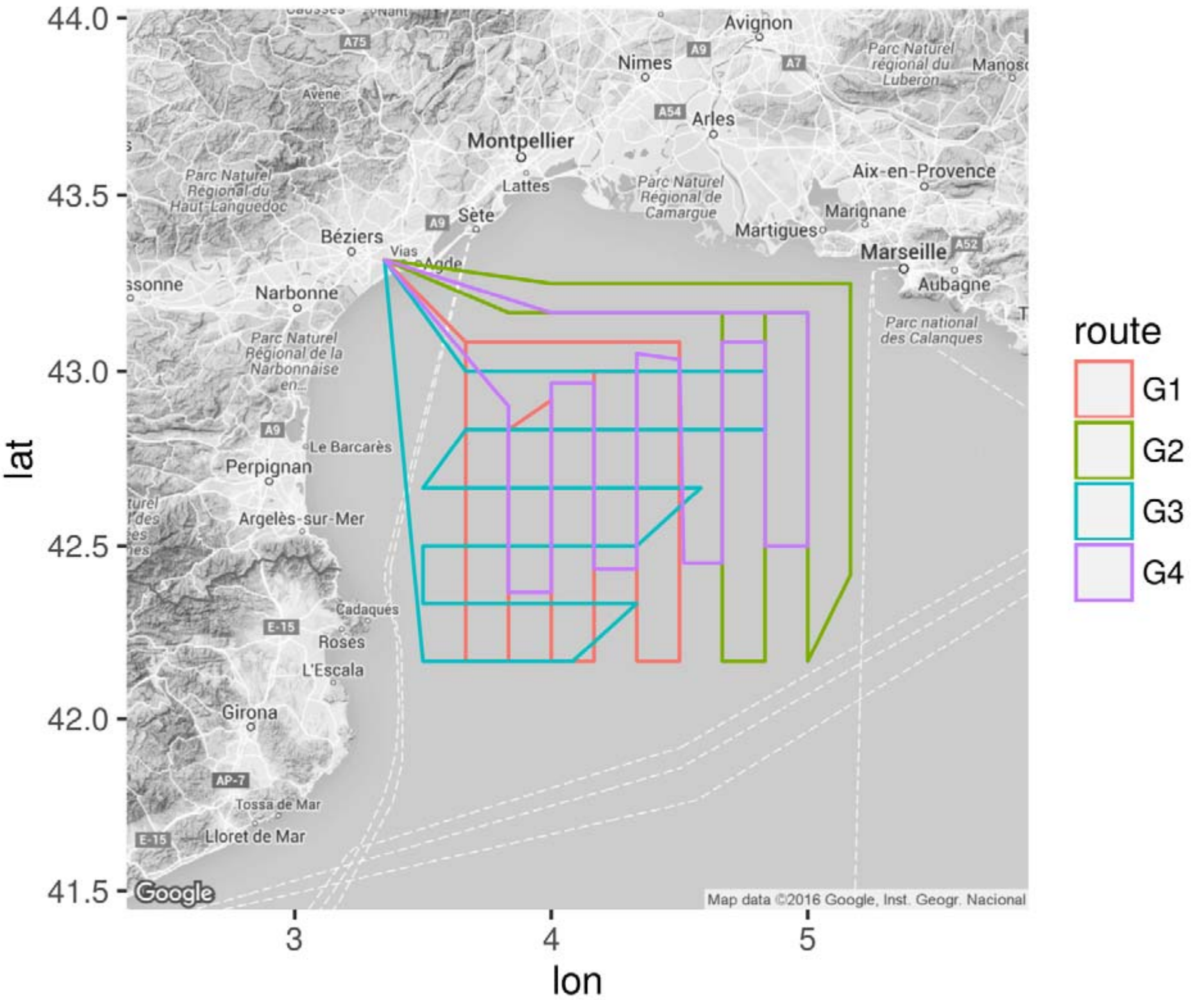

Figure 1. Maps of the different routes followed for the aerial surveys above the Gulf of Lions in the Northwestern Mediterranean.

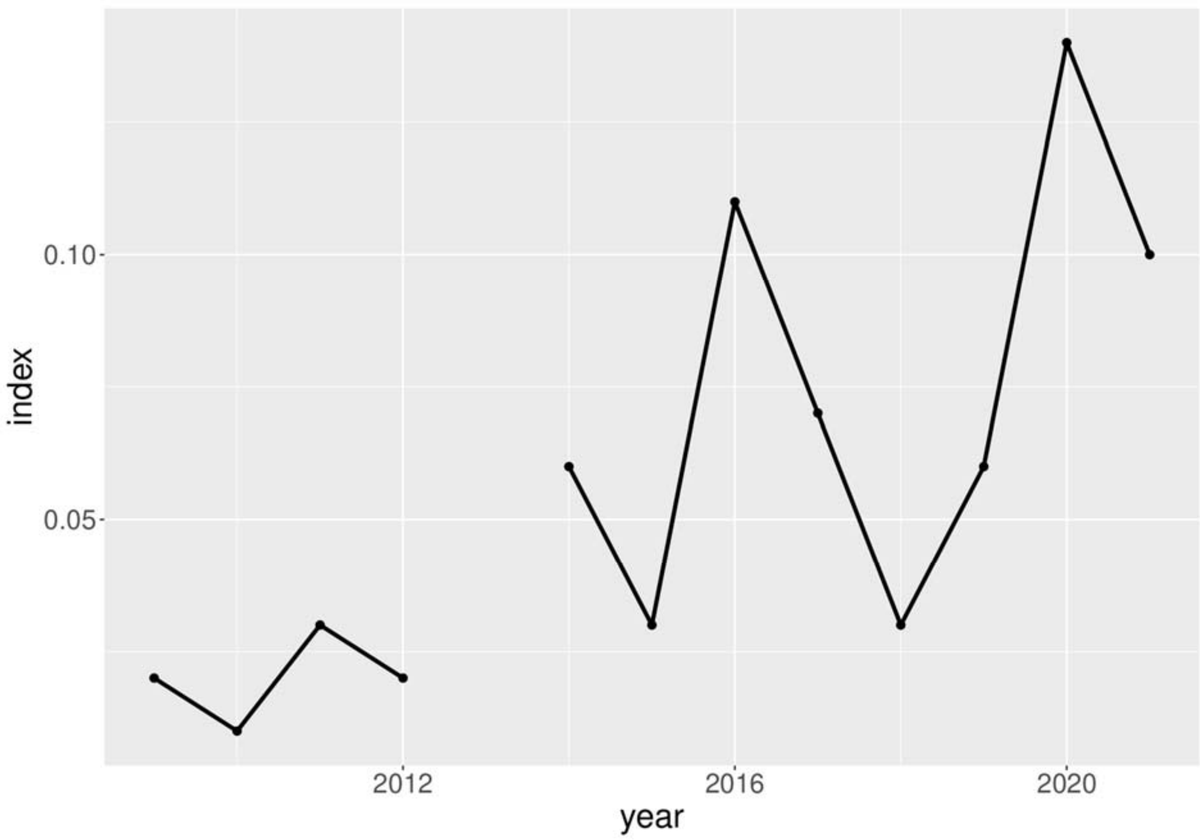

Figure 2. Estimated density of schools over time, from 2009 through to 2021.