REPORT OF THE 2021 ICCAT GBYP WORKSHOP ON ELECTRONIC TAGGING FOR ATLANTIC BLUEFIN TUNA

(Online, 15 –16 March 2021)

SUMMARY

The online GBYP Electronic Tagging Workshop was held from 15 to 16 March 2021 with the specific objectives to identify the main knowledge gaps on Atlantic bluefin tuna spatial patterns, update the status of ongoing BFT electronic tagging programs, aiming at finding potential synergies among national and ICCAT programs, elaborate a list, defining priorities of research needs related to BFT spatial patterns, aiming at improving stock assessment and MSE related modelling and, finally, to agree on the best electronic tagging methodologies to fulfil the objectives derived from the SCRS research needs.

RÉSUMÉ

L'atelier sur le marquage électronique du GBYP s'est tenu en ligne les 15 et 16 mars 2021 avec pour objectifs spécifiques d'identifier les principales lacunes dans les connaissances sur les schémas spatiaux du thon rouge de l'Atlantique, de mettre à jour la situation des programmes de marquage électronique du thon rouge de l'Atlantique en cours, afin de trouver des synergies potentielles entre les programmes nationaux et ceux de l'ICCAT, d'élaborer une liste définissant les priorités des besoins de recherche liés aux schémas spatiaux du thon rouge de l'Atlantique, afin d'améliorer l'évaluation des stocks et la modélisation de la MSE et, enfin, de convenir des meilleures méthodologies de marquage électronique pour atteindre les objectifs dérivés des besoins de recherche du SCRS.

RESUMEN

El Taller de marcado electrónico en línea del GBYP se celebró del 15 al 16 de marzo de 2021 con los objetivos específicos de identificar las principales lagunas en los conocimientos sobre los patrones espaciales del atún rojo del Atlántico, actualizar el estado de los programas en curso de marcado electrónico de atún rojo con el objetivo de hallar posibles sinergias entre los programas nacionales y los de ICCAT, elaborar una lista definiendo las prioridades en cuanto a necesidades de investigación relacionadas con los patrones espaciales del atún rojo, destinadas a mejorar las evaluaciones de stock y la modelación relacionada con la MSE y, por último, acordar las mejores metodologías de marcado electrónico para cumplir los objetivos derivados de las necesidades en cuanto a investigación al SCRS.

KEYWORDS

Bluefin tuna, tagging, spawning migrations, stock identification, data collections

1. Opening and meeting arrangements

The online GBYP electronic tagging workshop was held from 15 to 16 March 2021. Francisco Alemany, the GBYP coordinator and Enrique Rodríguez-Marín, the eastern BFT rapporteur, opened the meeting and served as Co-Chairs. They welcomed all the participants (the Group) and wished them a fruitful meeting. They reminded the Group that this Workshop has been postponed for a year due to the coronavirus pandemic. Also, they informed the Group about the objectives of the Workshop and the agenda, which are included in the **Appendix 1**. They explained that other issues related to the tagging will be discussed during the next presential workshop.

Mauricio Ortiz gave a short presentation about the procedures and logistics of an online meeting and provided short guidelines on the use of Microsoft Teams.

The List of Participants is included in the **Appendix 2**. The list of presentations given at the Workshop is included in the **Appendix 3**, along with their authors. Simon Dedman, Enrique Rodríguez-Marín and Stasa Tensek served as rapporteurs.

2. Short presentations on current BFT tagging programs

Tagging by GBYP

Francisco Alemany gave the presentation on tagging by GBYP. He explained that immediate objective of the tagging programme is to provide information on spatiotemporal patterns of BFT distribution useful for management purposes and that currently it is used within MSE framework. GBYP electronic tags repository includes datasets resulting from GBYP funded tagging activities, those provided by other institutions through collaboration agreements and those acquired through data recovery program. Currently there are 1067 pop-up satellite archival tags (PSATs) integrated in the provisional database and the Shiny visualisation tool was developed for maps plotting and data filtering. The official electronic tags database is currently being developed by the ICCAT Secretariat. Dr Alemany gave an overview of electronic tagging campaigns between 2011 and 2020 and enumerated several problems that have been faced in that period, such as technical problems with the tags' hardware (broken pin, battery issue), premature detachment and potential errors in geoprocessing. He also stressed that tags retention times significantly increased during last years, due to the methodological improvements, such as using reinforced tethers/titanium darts, loop, tagging on board, deep insertions etc. Finally, he concluded that it is worth to invest in electronic tagging programs and that huge collaborative efforts and broad databases are required to answer the questions relevant for the proper management of the species. The short-term tagging plans were also presented.

Tagging in Skagerrak

Andreas Sundelöf gave the presentation on tagging in Skagerrak. In the period 2017-2020 both PSATs and acoustic tags were deployed by SLU and DTU. The tags were deployed on adult BFT and it seems that from year to year bigger BFT individuals are encountered. With reference to acoustic tagging, the infrastructure, such as acoustic loggers, is already available in Skagerrak and it is possible to deploy acoustic gates. The tags demonstrated long survival rates and it was documented that a large number of individuals return to the same area after a year cycle. Dr Sundelöf explained that fish is captured using experienced voluntary anglers and tagging is done on board the tagging platform for 2-4 minutes, also including taking a sample of blood and muscle. Finally, he concluded enumerating reasons that make Skagerrak an excellent area for tags deployment.

Tagging by Fisheries and Oceans Canada

Alex Dalton gave the presentation on tagging by Fisheries and Oceans Canada, including collaboration with different institutions and fishing industry. Tags are generally deployed in 5 areas: Gulf of Maine, Southwest Nova Scotia, Gulf of Saint Lawrence, Canso and Newfoundland. There is a high frequency of premature pop-offs, although lately the average deployment length has increased. After trying different methods, last years fish have been tagged on board, using tether plus loop. The best fishing method appears to be rod and reel. One of the greatest challenges is to keep consistency in tagging vessels being used in Newfoundland, given that the vessels suitable for bringing fish on board for tagging, such as those that have a platform on sea level, are not prevalent in the Canadian fishing fleet. Other challenges include analysing older data from the Microwave Telemetry tags and newer data from LOTEK tags, as well as determining the deployment settings for the tags, especially for a one-year long deployments.

Tagging by Stanford University

Barbara Block gave the presentation on tagging by Tag a Giant at Stanford University, mainly focusing on deployments carried out in recent years (2019, 2020). Tagging of their team has focused in two western locations Canada and North Carolina where bluefin are easily accessible for tagging. She demonstrated that tags put out in the Gulf of St. Lawrence in Canada primarily go to the Gulf of Mexico, but a few fish enter the Mediterranean, and some move along the North American shelf and visit the region of the Slope Sea. More than half of the Canada release fish have also been double tagged, or individually tagged with acoustic tags (>200). Acoustic information from 2009-2019 enabled developing a model for keeping tracks of the individual fish and enabled a Bayesian model that outputs a probability of detection of entering a spatial area. This spatial mark recapture data provides the data for determining mortality indices for the populations in the area. Acoustic tags also allow comparing outputs from different geolocation models (GPE3 and SSM) and the Stanford team is currently working on examining how statistically to incorporate these high-quality hits from receivers into existing geolocation track models. Canada currently has a 13-year time series (2007-2010). The North Carolina datasets provide 25 years of information (1996-2020) from both archival and satellite tags and are provide data from individuals of probably Eastern and Slope Sea origin and fewer fish of Gulf of Mexico origin. None of these fish entered the Gulf of Mexico. Tagging done around the British Isles, in collaboration with the UK and Irish teams, enabled a transfer of methods for big fish tagging to these regions and demonstrates most tagged Bluefin remain in the eastern Atlantic with only few crossing into the western Atlantic. No fish has gone to the Gulf of Mexico but many have gone into the Mediterranean Sea. Testing Lotek PSAT-Flex tags demonstrated very good performance thus far with 90% reporting for up to 9 month duration. Tagging in the Eastern Mediterranean in collaboration with an Israeli team showed retention of 1.4 year tags in the Mediterranean and wide ranging movements throughout the Mediterranean Sea. To date fish have entered into the Adriatic but not the Black Sea. These fish show warm thermal records, in the eastern Mediterranean. Dr. Block also highlighted some geolocation issues their team has been working on including problems when using the GPE3 model which sometimes does not show entrance to the Mediterranean or more rarely into the Gulf of Mexico, although it has been demonstrated by other geoprocessing models and time series of depth and temperature t have moved into the spawning areas. This problem potentially affects 20-25% of the tracks. Her team is currently working to solve this problem and further improve geolocation models, to better understand how or why the GPE3 model has more trouble entering into these narrow regions. The Group recommended to have more than one model run simultaneously to do some comparisons.

Tagging in the Ligurian Sea

Fulvio Garibaldi gave the presentation on tagging in the Ligurian Sea (Western Mediterranean). From 2018-2020 11 PSATs were deployed and 150 conventional tags, mainly on juveniles. Lot of technical problems were faced with PSATs, including premature detachment and MiniPAT battery issue. Dr Garibaldi concluded that more information on BFT migration in the Mediterranean is needed, starting from the pre-spawning season in order to ascertain the possible reproductive and post-reproductive behaviour of the "resident" Mediterranean population.

Tagging by Thunnus UK

Matthew Witt gave the presentation on tagging by Thunnus UK. In the English Channel 33 PSATs were deployed and remained attached on fish in average for more than 250 days. In 2018 and 2019 40% and 63% entered the Mediterranean during spawning season. Other movements were towards the western Atlantic and to the Bay of Biscay. Around 35-40% of tags were recovered in the area where they were deployed showing homing behaviour. The plans for 2021 include tagging with MiniPATs and acoustic tags.

Tagging by AZTI

Haritz Arrizabalaga gave the presentation on tagging by AZTI, concentrating on internal archival tags, although the team also deployed conventional tags and PSATs. The tags were deployed in the Bay of Biscay, which is one of the main juveniles feeding grounds in the Atlantic and to which BFT show strong fidelity. Up to now, 136 internal tags have been implanted on age 1+ juveniles, and 7 have been recovered, with times at liberty ranging between 1 and 10 years. Recently the recovery rates are increasing thanks to ICCAT ROPs on farms. The results show animal residency in the Atlantic until at least age 5, migrations into the Mediterranean between age 6 and 8-11, which could suggest a delayed maturity schedule, compared to the one assumed in the Mediterranean. The 7 archival tags recorded 17.3 years of information out of the 35.5 years at liberty, and showed signals of poor performance of some sensors. Future recommendations include deploying more internal archival tags on juveniles, both in the Atlantic and in the Mediterranean, to inform about first maturity and spawning fraction, as well as to understand resident versus migrant behaviours. The importance of biological sampling and genetic analyses was highlighted, as well as extracting the otolith when a fish is recaptured.

Tagging off Norway

Keno Ferter gave the presentation on tagging off Norway during 2020, which included deployment of conventional tags and 5 MiniPATs. Conventional tags were deployed along the side the recreational fishing boats using tagging hammer method developed by LPRC. PSATs were deployed from a new purpose-build boat which includes an aluminium ramp which can be lowered into the water. They were deployed on board using titanium darts and a loop tether. The plans for 2021 include implanting 10 MiniPATs equipped with tethers and darts from Barbara Block's team.

Tagging by Scandinavian BFT Marathon

Kim Aarestrup gave the presentation on Scandinavian BFT Marathon which included tagging in Skagerrak and Kattegat from 2017-2020 by Danish, Swedish and German team. Different types of tags were implanted and some fish were double tagged. Tagging with X-Tag showed some good results and it was recommended to further investigate that model. DTU make their own attachments based on Domeier anchors and have 100 % surfacing on the programmed date (12 months) with X-tags using that attachment. One one-year track from tag implanted on adult fish in 2019 showed that fish did not enter the Mediterranean during the spawning season. Well over 90% of the possible fish returned to the same general tagging area the following year. Initial results show the Skagerrak/Kattegat and Norwegian fish are part of the same group. Biotelemetry has the potential to substantially increased necessary management information, but the method needs to be adapted to the information required to maximise its effect. Dr Aarestrup recommended combination of PSATs and acoustic tags, PSATs with DST tags and 2-year PSAT deployments. The multiyear detection at acoustic arrays allows for many high-end inputs to management in terms of survival, behaviour variability and model improvements.

Tagging off Ireland

Niall O'Maoileidigh gave the presentation on tagging off Ireland. The electronic tagging began in 2003, but than it was suspended because of the sudden decrease of BFT after 2005. Scientific research was again initiated in 2015/2016 when BFT began to appear in Irish recreational fisheries captures again. A great number of tagging operations were carried out in collaboration with the Stanford University and with other institutions including ICCAT. Tags are deployed on board keeping consistent methodology. Most of the tags were equipped with Block lab anchors and tethers, while the others were equipped with Domeier anchor and a loop anchor. Different types of tags were deployed, including MiniPATs and Lotek FLEX tags. The tag retention time generally proves to be long and therefore lot of spawning events were caught. Marine Institute has also done accelerometery tagging with Trinity College.

Tagging by Large Pelagics Research Center

Molly Lutcavage gave the presentation on tagging by Large Pelagics Research Center. The tagging has been done since 1997 in Gulf of Maine and expanded to SW Nova Scotia in 2003. In total they accumulated over 850 tracks. Multi-year observation informed about shifts in BFT behaviour and movement patterns, probably due to climate changes and/ ecosystem shifts (e.g., transition from a high availability of adults to juveniles in the Gulf of Maine in the 2000's, and vice versa since around 2017). Therefore, mixing and spawning grounds may be dynamic, and change over time, so few years of data are not enough to describe the full picture. The performance of different tags has been tested and showed lots of problems and multiple technical failures. Although tags have been produced since 1996, their performance has not significantly evolved, nor has their cost declined. It was advised that the whole scientific community demand innovation and performance standards from the tag producers. They should at least provide one year of data to inform about spawning. Dr Lutcavage informed that Microwave Telemetry has blacklisted her team because of their criticism of previous X-tag performance issues. She also concluded that short PSAT missions may contribute to evaluation of behaviour and mixing, but cannot depict spawning site fidelity or long-term dispersal or migration patterns. For MSE considerations, analysts should understand the limits of PSAT tag data e.g., geolocation error, and make sure that the biological assumptions are valid. For example, the previous assumptions about spawning sites in Atlantic prove not to be correct, given that the importance of the Slope Sea has been demonstrated and reiterated by other presenters in the workshop.

Tagging off Portugal

Pedro Lino gave the presentation on tagging off Portugal done in Tunipex trap. The trap is located in the Atlantic Ocean and catches BFT both entering and exiting the Mediterranean. Tags have been deployed there for ICCAT since 2016. In order to explore the reasons of premature detachment, a special trial was made in 2018, showing retention time up to 4-5 months and no apparent differences between underwater and onboard tag deployment. Future plans include comparison of inserting tags deep in the muscle versus through pterygiophores or through the spines, in order to improve the retention rates, and, at the same time, possibly lessen the impact on fish. The presentation also focused on data/time/funds wasted due to tag failure.

Tagging by Ifremer

Tristan Rouyer gave the presentation on tagging by Ifremer. The tagging campaigns have been carried out in the Atlantic (large fish in Brittany and smaller ones in Bay of Biscay), Gulf of Lions (post spawning fish and young fish) and south of Malta (adult fish). South of Malta tags are deployed in farms' cages and purse seiners' nets from which fish are directly caught using hand line and no accidental morality has been caused so far. Several ongoing projects connected to tagging include aerial survey, developing tags and sensors and linking growth, energetics and migrations.

3. Presentation on the use of electronic tagging data within the framework of BFT MSE modelling

Emilius Aalto gave the presentation on the utility of electronic tags for MSE process. There are currently more than 1400 datasets available for MSE. Most of them are assigned to the Western stock, although the majority are unassigned. Tag data represent distribution/movement of stock biomass and are used to inform the biological system within the operating model. Currently, ICCAT uses the M3 mixing model, which is an age structured two-stock model, spatially structured with a quarterly timestep. Mixing model uses a simplified mixing structure and has 7 statistical areas defined, which also capture key differences between two stocks. Therefore, tag daily movement data are converted into a likelihood to transition between these areas on a quarterly basis. These quarterly transitions are converted into a simplified matrix for each BFT age class (for a total of three different age classes) each quarter and each stock. There are not enough data for year-to-year differences, so multiple-year data are pulled together. The movement data are used by the model with a certain level of weighting. These data are co-equal with some other data like catch data or stock of origin to weight/penalize model results during model fitting. Therefore, if simulated stock movement deviates greatly from what is expected (according to other data), the movement data are penalized accordingly. Nevertheless, if movement data result in a better fit to the data, they are tolerated, even if they deviate from other data. Most of the datasets have not been genetically stock assigned, but some can be assigned according to movement to spawning ground (i.e. Gulf of Mexico and Mediterranean). Nevertheless, since the M3 model uses only assigned data, most of the datasets collected so far cannot be immediately used, until they get stock assigned. Lack of movement data for younger age categories represents other gap in knowledge, which is especially accented for the Western fish. There are also some gaps in the regional/quarterly transitions data, in terms that they are not evenly distributed. Generally, there are more tagging data in the West. Another gap in knowledge is spawning outside of the Mediterranean and Gulf of Mexico spawning grounds, which has not been taking into account yet. It may include potential additional stocks, although its importance to management is still not known. Another gap in knowledge is the complexity of movements along life cycle, because the majority of tracks are single-year and not multi-year and, therefore, cannot show the changes in animal movement patterns as they age.

The Group commented that the fishing data may not be the best input for penalising tagging data, given that they are CPUE and area dependent. It was explained that the model produces time series of biomass simulations based on different datasets, which do not always match with the observed. Therefore, mathematical penalties are created and weighted in proportion of the mismatch. In any case, several different weighing schemes on data components have already been explored and assigning weights is still an open question, subject to the MSE technical group recommendations.

The Group discussed about the great number of stock unassigned tracks which cannot be used for the MSE model, although potentially could provide a lot of information. Therefore, the Group identified assigning more tracks as a high priority. It was decided to check if, for some of these tracks, an archived biological sample could be recovered, which then be genotyped and assigned.

The Group commented that the South Atlantic statistical area used for MSE purposes may not be properly defined and therefore may create bias. It was recommended to reconsider shifting its upper boundary towards south, in order to exclude the Azores. The Group asked if different maturing schedule between two stocks may create bias, but it was explained that model currently has three age classes for movements (1-4, 5-8, 9+ years old), so it can support Eastern fish maturing younger.

4. Open discussions

Open discussions were guided using pre-defined questions and tips that are included in the **Appendix 4.**

4.1 Identification of SCRS research needs in the field

The group recommended to simplify research needs and defined a series of potential questions for each spawning ground (Gulf of Mexico, Mediterranean, Slope Sea):

1. At what age and when does a BFT go to spawn?
2. Where does the BFT go to spawn within the spawning ground?
3. How long does a BFT stay on a specific spawning ground and does it change with age?
4. Where does a spawning BFT go after spawning to forage, is there fidelity to this region?
5. What is the mortality of the distinct spawning populations?
6. How do male and female BFT behave?

Fidelity to spawning area

The Group commented that potential fidelity to spawning ground and areas within spawning ground should be especially investigated, including possible change of patterns over the life cycle and related to climate change and stock size.

Spawning in the Slope Sea

The Group also advised to reconsider how the fish are assigned to a stock, with special reference to the Slope Sea spawners. Currently there are lot of unassigned tracks, representing fish that did not enter either Mediterranean or Gulf of Mexico. The researchers that tagged fish in the NW Atlantic proved they are sexually mature earlier than assumed for West BFT, based on biological, histological and endocrine studies. The majority of spawning-capable fish tagged by LPRC in Western Atlantic went to the Slope Sea, presumably to spawn and the importance of that area for recruitment may be bigger than currently assumed. There are also larger fish that did not enter GOM during the spawning period. These fish also present differences to other BFT population, based on results of genetic and micro-constituent analysis. Therefore, it was advised that more research is done on life history and basic biology of BFT, and not solely depend on tagging data. Also, it was advised to be careful about assumptions if the knowledge is still scarce.

BFT habitat preferences

The Group recommended not to concentrate only on the BFT tracks *i.e.* horizontal movements, but also investigate BFT depth and temperature preferences. Habitat preferences can be possibly used for improving abundance indices, predict where BFT will move to and how the movement patterns will change in the future.

4.2 Main problems affecting electronic tagging programs and ways to solve them

Tag performance

The Group discussed technical problems affecting the performance of tags, such as battery issues, pin broke and memory limitations, and concluded that many of these are probably derived from the lack of competition among the tag manufacturers. The lack of adequate tethers was also identified as a problem. It was advised that tag manufacturers should be requested to maintain performance standards. In order to obtain more bargaining power, it would be beneficial if different species scientists unite with common requests. A common front is likely to push the tag manufacturers to innovation and competition, which would hopefully lead to better tags performance and, finally, lower prices. In any case, in the absence of the good performance tags to count upon, it was advised to investigate the combination of different tag types deployed on the same fish, which may optimize the data returns.

Lack of long-term tracking data

The lack of long-term tracking data was discussed as well, because of its limits to catch shifts in an individual migration behavior. Some experts observed that Wildlife Computer PSATs could last up to two years in the past and it is possible to obtain the same performance if the manufacturer solves the current battery problem. As for the Lotek PSATs, they have currently proved fully successful for periods up to 9 months and probably they can also endure up to 1 year, but the corresponding study is still ongoing. Microwave PSATs are also successful for the periods up to 1 year and will potentially be able to last for 2 years. Acoustic tagging offer a good potential for long term tracking data potentially lasting up to a decade on the same fish, with possibilities for detailed verified positions supplementing and alleviating the need for advanced modelling. Regarding the internal archival tags, they proved to be able to store up to 6 years of data. Nevertheless, it seems that the performance of internal tags is suboptimal because they often present problems with light sensors after only two years into their deployments. Therefore, it was advised to push manufacturers for technical improvements to increase duration of batteries and memories and to improve sensor performance.

Reliability of geolocation algorithms

The Group also discussed the reliability of different geolocation algorithms, since different processing models usually result in different tracks. The Stanford team informed that they are currently in touch with the Wildlife Computers about improving of GPE3 model, given that it is sometimes appears to miss entrance into the Gulf of Mexico or the Mediterranean. The Group concluded that algorithms will always have uncertainties. In addition, it is pointless to compare different algorithm results, without having a true reference from double tagging. It was recommended to move to model averaging, similarly to what is done in the stock assessment exercise, which may be the way to solve this problem. Another recommendation is to use different tag types on the same fish to be able to compare results and address uncertainties. The DTU team informed that they are currently working on the model that combines outcomes from different tags technology. It was also recommended that ICCAT carry out the model validation exercise and use uniform practices.

Tag insertion methodologies

The tag insertion methodologies and attachment equipment were discussed as well, given that the improper tag deployment may lead to premature PSAT detachment or even fish mortality. It was acknowledged that many tagging teams have proven their ability to insert a PSAT which stays attached for a year and therefore other teams may benefit from their experience. It was acknowledged that the GBYP technical tagging workshop in Olhão resulted in increase in tag retention rates for many tagging teams, which corroborates the importance of collaboration. It was also concluded that common tagging protocols should be developed to ensure good tag retention and minimize fish stress and injuries. The methods for PSAT deployment were briefly discussed and it was concluded that underwater tagging is not recommended. The Group agreed that on board tagging proves to achieve the best results, although it was demonstrated that tagging alongside the boat can achieve good results as well, and it provides advantages considering animal welfare. Nevertheless, tagging alongside the boat it is not recommended for less experienced taggers and crews. The performance of tethers was briefly discussed as well, as it is demonstrated that they sometimes break and therefore cause premature detachments. It was recommended not to use the Wildlife Computers tether without a second attachment (loop), although it was commented that the second point of attachment could be more challenging to add in for in-water tagging. As for the internal archival tags deployment, it was acknowledged that fish handling is challenging, especially as they get bigger. It was recommended to carefully plan the experiments. Optimally, a fish has to be tagged within its thermal neutral zone and not after it has eaten a big meal. The use of traps and farms as tagging platforms was also discussed. The Ifremer team explained their strategy, apparently causing zero mortality, consisting in using hand line for taking out the fish from a purse seine or a cage, and putting it on a deck for tagging.

Low recovery rates

The Group also discussed the problem of low recovery rates and it was noted that, for PSATs, some actions may be done, such as taking advantage of foraging ground homing behavior and use of goniometers. It was also acknowledged that it is necessary to improve tag recovery awareness and rewards programs. The Group recommended to discuss recapture policies on the SCRS level.

Acoustic tagging

The acoustic tagging was discussed as well. The Group noted the lack of enough acoustic receivers in strategic places. IEO team informed the Group that they are working with other teams and European Tracking Network on installing the acoustic array in the Strait of Gibraltar. The feasibility of the array has been proven, although it has complex physical characteristics. It was acknowledged that it is a very complex project, but since it is of utmost interest to the international BFT community, it was recommended that ICCAT, as well as other scientific groups, provide their support. The Group commented that at least closing one side of the Gibraltar Strait would be important for BFT science, if closing the entire strait is not possible. The Group also informed about the current negotiations through European Tracking Network to install receivers in all Mediterranean gliders and buoys of Argos and concluded that ICCAT should establish direct contact with the company and push for improvements, as it would be a great opportunity to obtain a lot of acoustic receivers in the Mediterranean.

Stock assignment of the tagged fish

The Group also discussed about the stock of origin of the tagged fish and concluded that protocols must be in place in order to always take a genetic sample of the tagged fish, even though the stock assignment methods are still not standardized. Regarding the methods of genetic analysis for stock assignment, AZTI team has developed and published a method for stock assignment using a set of 96 SNPs. The method is currently used to feed the MSE with Stock of Origin data, and has a small margin of error. NOAA got similar results as AZTI. Stanford team also developed their method. The Group recommended holding a meeting on genetics to compare the methods for stock assignments and standardize them, with special attention to the Slope Sea individuals.

4.3 Specific recommendations

Defining tagging needs

The Group concluded that, before starting any tagging campaign, the objectives of the research should be clear and well defined, so as to properly design the study and be able to choose the most appropriate tag type or a combination of tag types that will be deployed. The settings of the electronic tags should also be modified according to the specific objectives of the research. The main gaps should be identified using the MSE movement matrices (probability of transitions between spatial boxes) and accordingly decide not only where and when to tag, but also which age class to target. In order to focus tagging, it was recommended to establish a SCRS subgroup including modelling experts to address questions where and when to tag, taking also into account where recovery is available.

Some potentially interesting tagging campaigns

The tagging campaigns should be designed to target gaps in MSE movement matrices, such as tagging more fish in the East and tagging younger fish with known stock of origin. From the biological point of view, tagging Eastern Mediterranean BFT seems interesting because it may answer some current questions on potentially distinctive behaviour of these fish. Since knowledge on the movements of younger fish in the NW Atlantic is still scarce, tagging of 3-5 years old BFT there may provide some interesting insights as well. Tagging of E-BFT off Carolina (USA) can also reveal East to West movement and is important for keeping the time series continuity to reveal potential changes in BFT movement patterns due to climate change.

Internal archival vs. PSAT tags

The Group discussed different tag types currently available on the market and concluded that there is a range of possibilities to choose from, depending on the particular question the study intends to answer. The internal archival tags are potentially able to answer the questions on when does a fish mature or when does it enter a spawning ground and are, therefore, ideal to be used on young fish. On the contrary, PSATs can be used on mature fish for tracking movements up to one year, but also hold potential for two-year deployments. In addition, it has to be taken into account that the price of internal tags is much lower, but their recovery rates are much lower as well. The actual recovery rate in Western Atlantic is 20%, while in the Mediterranean it is even much lower. Other potential problems with internal tags are low data resolution over longer deployments and sensor issues. Nevertheless, the Group recommended that more archival internal tags be used, which are able to produce multi-year tracks, long enough to answer some of the actual questions on BFT reproductive biology. Internal tagging should target younger fish in both stocks.

SCRS technical subgroup on tagging

Given that the expert discussions related to tagging are important for various ICCAT species and not just for BFT, the Group recommended to reactivate the ad hoc tagging working group at SCRS. The tag recovery programs and rewards should be discussed as well.

Data collection and data sharing

Since the data recovery accelerated in the recent years, it was concluded that it is ICCAT's role to bring results together to enable global analysis, for better modelling and management of BFT. Therefore, a repository of tagging datasets should be created within ICCAT. Nevertheless, it was acknowledged that data sharing policies may present a big challenge. Therefore, clear data sharing agreements should be in place to regulate the access to the data and the publication policy. It was explained that the new ICCAT data policy has already been drafted and presented to the Commission on the last meeting held online, but it still has not been adopted.

Next GBYP tagging workshop

The GBYP Coordinator announced that the next tagging workshop will be held at the end of 2021 or in the beginning of 2022. The intention is to hold a presential meeting. The workshop will focus on other topics related to tagging, such as data sharing policy and standards of quality of tracks used for modelling purposes.

Appendix 1

Workshop Objectives and Agenda

Objectives

The specific objectives are:

- to identify the main knowledge gaps on Atlantic Bluefin Tuna spatial patterns
- to update the status of ongoing BFT electronic tagging programs, aiming to find potential synergies among national and ICCAT programs
- to elaborate a list, defining priorities, of research needs related to BFT spatial patterns aiming to improve stock assessment and MSE related modelling
- to agree on the best electronic tagging methodologies (type of tags, tag deployment methods, tagging time and areas, target population fraction…) to fulfil the objectives derived from SCRS research needs

Agenda

1. Opening
2. Short presentations on current BFT tagging programs
3. Presentation on the use of electronic tagging data within the framework of BFT MSE modelling
4. Open discussion sessions on:

   a) identification of main knowledge gaps on BFT spatial patterns
   b) identification of SCRS research needs in this field
   c) electronic tagging methodologies to address SCRS research needs

5. Elaboration of concrete recommendations for 2021 BFT tagging campaigns
6. Closure

Appendix 2

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Appendix 3

List of Presentations

No.	*Title*	*Author*
1	GBYP e-Tagging program 2011-2020	GBYP team
2	Tagging of Large Adult BFT in Skagerrak	Andreas Sundelöf, Gustav Hellström and Tomas Brodin (SLU); Kim Aarestrup, Kim Birnie-Gauvin, Brian Mackenzie (DTU)
3	Fisheries and Oceans Canada (DFO) Bluefin Tuna e-tagging Program	Alex Dalton at al. (DFO)
4	Atlantic Bluefin Tuna Tagging Update	Barbara Block et al. (Stanford University)
5	Thunnus UK: Atlantic Bluefin Tuna off the United Kingdom	David Righton, Samantha Smith and Jeroen van der Kooij (Cefas); Lucy Hawkes, Tom Horton and Matthew Witt (University of Exeter); Barbara Block and Robert Schallert (Stanford University)
6	Satellite and Conventional Tagging of BFT in Monaco Waters (Ligurian Sea, Western Mediterranean)	F. Garibaldi (WWF Mediterranean), University of Genova); N. Rasore, L. Lanteri (University of Genova); D. Gamba, G. Benoit, P. Garziglia (Yacht Club Monaco); A. Ducroix (Mediterranean Sport Fishing); A. Buzzi (WWF Mediterranean)
7	Internal Archival Tags for Long Term Insights into BFT Movements	Arregi, N. Goñi, I. Onandia, I. Fraile, J. Santiago, H. Arrizabalaga (AZTI); M. Lutcavage, C.H. Lam, B. Galuardi
8	Tagging of Atlantic Bluefin Tuna (Thunnus thynnus) in Norway during 2020	Keno Ferter, Otte Bjelland, Jan Hinriksson, Leif Nøttestad (Institute of Marine Research)
9	Scandinavian Bluefin Marathon	Kim Aarestrup (DTU) et al. at DTU and SLU
10	no title (Tagging off Ireland, Research programme 2015-2021)	Niall O'Maoileidigh, Alan Drumm, Hugo Maxwell, Ross O'Neill, Joe Cooney (Marine Institute); Barbara Block, Mike Castleton, Robbie Schallert, Mike Stokesbury
11	PSAT Tagging in the NW Atlantic, 1997-2020, Conclusions	Molly Lutcavage, Tim Lam (Large Pelagics Research Center, UMass Boston); Ben Galuardi (Dartmouth, USA)
12	Electronic Tagging of Adult Bluefin Tuna in a Portuguese Trap in the Eastern Atlantic Ocean	Pedro G. Lino, Catarina C. Santos, Rui Coelho, Maria Nunes, Alfredo Poço, Rubén Muñoz-Lechuga & Morikawa Hirofumi (IPMA and Tunipex)
13	Ongoing French Tagging Operations on BFT	Tristan Rouyer (Ifremer)
14	Use of Tagging Data in ICCAT's Atlantic Bluefin Tuna MSE Process	Emilius Aalto, Matthew Lauretta, John Walter, Barbara Block Stanford University, NOAA

Appendix 4

Guidelines for GBYP Tagging Worshop Group Discussions

RESEARCH NEEDS: SPECIFIC QUESTIONS POTENTIALLY ADRESSED BY E-TAGGING

1. Characterization of all 'transitions' between spatial boxes in MSE operating models (see specific lacking ones in Emil's presentation)
2. Proportion of each stock in each statistical area at a given period…
3. Proportion and characterization of spawners in different spawning areas of both stocks (Slope Sea/GOM; Med/alternative spawning areas in the Atlantic)
4. Proportion of adults remaining in the Med after spawning (resident population?)
5. Percentage of adult fish skipping spawning
6. Detection and characterization of new spawning areas
7. Proportion of juveniles from the different Med spawning areas that remain in the Med nursery areas
8. Proportion of Eastern juveniles leaving the Med: when they leave, how long they remain in the Atlantic, are they of local origin or they can camo from alternative spawning areas in the Atlantic
9. Characterization of different spatial patterns (fidelity to specific feeding and spawning areas), do these patterns change over the life cycle?
10. Estimates of natural and fishing mortality
11. Modelling of fish behaviour, movements and migration

Objective: *Complete the list (point 4a), establish priorities (point 4b) and determine the best methodology to address each of them (potential uses and pros/cons of each type of e-tags…) (point 4c)*

MAIN PROBLEMS AFFECTING -ETAGGING PROGRAMS AND WAYS TO SOLVE THEM (Problems: *potential suggested solutions*)

1. Technological problems (battery issues, pin broke, memory limitations, high prices…, many derived from lack of competition among tag manufacturers -there are few companies>almost monopolistic scenario): *Common front to push the manufacturers to innovation and competition, collaboration with manufacturers, optimization of settings, …*
2. Lack of long-term tracking data to characterize shifts in individual migration behaviour: *focus tagging in key "transitional" stages, as late juveniles; use of long lasting archival/acoustic tags; push manufacturers for technological improvements to increase duration of batteries and memories….*
3. Reliability of geolocation algorithms (differential tag track processing algorithms can lead to very different patterns): *comparisons among different models, combined use of different types of tags….*
4. Attachment equipment and insertion methodologies inducing premature detachment of pop up due to death of fish or improper attachment methods: *Improve quality of equipment and insertion methods; protocols to minimize stress and injuries -but ensuring good retention- (Is onboard tagging, using low boats with windows and ramps at water level, or stretchers) the best method to reduce tagging mortality and ensure good tag attachment?, should the darts be inserted through pterygiophores or deep in the flesh?...);use of farms as tagging platforms; improve sampling strategies to minimize to effects of premature detachments…*
5. Low recovery rates: *Deployment strategies facilitating the recovery of the pop-up tags taking advantage of homing behaviour to specific feeding grounds, use of goniometers, improvement of tags recovery awareness and rewards programs…*
6. Lack of enough acoustic receivers in strategic places, mainly in the East: *Common front to push for improvement of European Tracking Network…*
7. Uncertainties about stock of origin of tagged fish: *Protocols for taking genetic samples of tagged fish.*

Objective:
Define a common strategy to overcome these common problems… (point 4c)

LIST OF SPECIFIC RECOMMENDATIONS (SHORT AND MID TERM)

From the discussions on the previous points, elaborate a list of specific recommendations on etags deployment strategies and methodologies (where, what, when, which and how deploy etags)

- **Priority considerations for tag allocations and distribution**
    - Tagging demonstrates that it meets research needs identified above
    - Previous/demonstrated expertise or partnering with such expertise
    - Cost-sharing or leveraging with fishing community (e.g. GBYP really cannot pay for vessel time)
    - Priority spatial/temporal locations:
        - Eastern Mediterranean (addresses 3, 6, 7 above)
        - others
        - For MSE
            - Need stock of origin (are there any fin clip out there that we can 'buy' back the stock of origin genetically)
            - need more East to West transitions

younger fish of known stock origin (8 GOM fish in dataset)

- **Create a community of practice for tagging, tag track reconciliation and data sharing**

1. Tagging protocols
    a. Tag attachment, fish handling and tag programming should follow norms developed by successful teams (we have numerous examples of what works and what does not work well)
    b. Genetic sample must be taken and provided to GBYP tissue bank from every fish

2. Track reconciliation
    a. Run existing tracks with multiple models, reconcile divergent patterns
    b. Create 'clean' GBYP master dataset of tracks

3. Data sharing agreements
    a. Goal is to for scientific community to be able to access and use a common dataset
    b. How do we achieve this?
    c. Time frame for PI to publish data, before opening up tracks and associated metadata