Appendix 3

Report of the ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (ICCAT GBYP)

(Activity report for the last part of Phase 9 and the first part of Phase 10 (2019-2020))

1. Introduction

The ICCAT Atlantic-wide Research Programme for Bluefin Tuna (GBYP) was officially adopted by the SCRS and the ICCAT Commission in 2008, and it started officially at the end of 2009, with the objectives of improving a) basic data collection, including fishery independent data; b) understanding of key biological and ecological processes and c) assessment models and provision of scientific advice on stock status. It was initially envisaged as a 6-year programme, but in 2014 the Commission, acknowledging the importance of the programme for bluefin tuna management, endorsed the GBYP Steering Committee (2015) and the SCRS recommendations (Report of Special Research Programmes – GBYP contained in the *Report for Biennial Period 2014-15, Part I (2014) - Vol. 2*) for extending the GBYP activities up to 2021. Consequently, the donors have maintained their budgetary support (EU 80%, other donors 20%) since then, allowing for the continuity of the programme. The general information about GBYP activities and its results, as well as on budgetary and other administrative issues of the GBYP programme, from the very beginning of the programme until today, are available on the GBYP webpage. All the relevant documents related to programme development, including final reports of every activity and the derived scientific papers, Annual Reports to the SCRS and European Union, GBYP workshops or Steering Committee meetings reports, are also readily available on the GBYP webpage.

The ninth phase of the GBYP officially started on 1 January 2019 following the signature of the Grant Agreement for the co-financing of the GBYP Phase 9 (SI2.795824) by the European Commission. Initial duration of the Phase was one year, but, in order to better adjust to the period of bluefin fishing and harvesting operations, which condition many GBYP activities, it was extended for four months, thus officially ending on 30 April 2020. The activities carried out during the first nine months of Phase 9 and their preliminary results were presented to the SCRS and the Commission in 2019 (Alemany *et al*., 2019) and approved. The tenth phase of the GBYP officially started, following an EU request, on 1 January 2020, after the signature of the Grant Agreement for co-financing of Phase 10 (SI2.819120) by the European Commission, with a planned duration of one year. Although these two GBYP phases have been partially developed in parallel, this has not caused any major problems since each phase has a different and well defined workplan and budget, and every cost can be assigned unequivocally to the activities detailed in the respective Grant Agreements.

In general, although several tasks have been affected due to the COVID-19 pandemic, most of the activities planned within both phases have been or are being implemented successfully. The activities in both phases have continued to be structured considering the same main lines of research established since the beginning of the programme, i.e. data recovery, biological studies, tagging, aerial surveys and modelling, but this does not mean that the workplans of these last two phases mimic those of the previous ones, since the specific activities are adapted every year in accordance with the SCRS research needs and Commission requests, continuously improving the methodologies and optimizing the working procedures year after year to increase the efficiency and quality of the advice.

All activities carried out throughout the GBYP Phase 9 and those launched during the first part of Phase 10, as well their final or preliminary results and the related coordination activities, are described and summarised in this report. Moreover, it also includes a proposal of activities to be carried out within Phase 11, for consideration and eventual support of the SCRS.

The COVID-19 pandemic affected the latest activities in Phase 9, such as a workshop on electronic tagging that had been planned for March 2020, which was postponed indefinitely at the very last moment, and a tagging activity also planned for March 2020, which was cancelled. Activities planned for the first semester of Phase 10 have also been heavily affected by the pandemic. Specifically, two workshops, one on the Potential use of Close-Kin methods for the Eastern ABFT stock assessment and another on ABFT Eastern stock larval index surveys coordination have been postponed. In addition, the 2020 aerial surveys were cancelled, as well a pilot study on growth in farms that was going to be carried out in Morocco in summer

2020, because of the restrictions on international travel. The lockdown measures and the temporary closure of the ICCAT Secretariat headquarters have also obliged the GBYP coordination team to change the usual working procedures, which has been using telecommuting facilities since March 2020 to manage the programme.

2. Coordination activities and general issues of GBYP programme management

The GBYP Steering Committee in Phase 9 has been composed by the SCRS Chair, the Western Bluefin Tuna Rapporteur, the Eastern Bluefin Tuna Rapporteur, the ICCAT Executive Secretary and/or his deputy. During 2019, one contracted external expert also acted as a full member of the GBYP SC. In order to define the workplan and refine the ongoing activities, the Steering Committee held one meeting in September 2019 and various online-meetings in May-June 2020. In addition, its members have been constantly informed by the GBYP Coordination Team about the status of the activities through detailed reports provided on a monthly basis, and they have been regularly consulted by email on many issues.

The GBYP Coordination Team has been composed of the GBYP Coordinator, the Assistant Coordinator and the Database Specialist. The ICCAT Secretariat has provided technical and administrative support for all GBYP activities on a daily basis. In Phase 9 a total of 6 calls for tenders and 6 official invitations were released, which resulted in 19 contracts awarded to various entities.

2.1 Financial aspects

In Phase 9 the GBYP budget has had the following funders (in order of contribution already received or committed): European Union (Grant Agreement) €1,400,000.00, United States of America €165,330.24, Japan €56,060.18, Tunisia €50,887.30, Turkey €41,428.12, Libya €34,294.50, Syria, €1,999.66 and ICCAT Secretariat €10,000.00. Thus, the total budget has been €1,750,000.00.

In Phase 10 the total budget is €2,000,000.00, thanks to the contributions from the following donors: European Union (Grant Agreement) €1,600,000.00, Algeria €105,479.22, Japan €68,344.70, Morocco €64,962.81, United States of America €64,000.00, Libya €20,775.11, Canada €19,252.55, Egypt €13,007.74, Tunisia €11,764.30, Albania €7,718.45, China, €4,401.12, Korea €4,054.67, Iceland €3,239.33, Chinese Taipei €3,000.00, ICCAT Secretariat €10,000.00.

The residual amounts of previous GBYP Phases were used to better balance the EU contribution and to compensate costs that were not covered by EU funding in various Phases. Additional eventual residuals from the amounts provided in Phase 10 will be used for the following Phases of GBYP. It should be noted that contributions for the current and previous GBYP Phases are still pending from some ICCAT CPCs.

The approved budget for Phase 9 and Phase10 is summarised in **Table 1**.

3. Summary of Phase 9 and Phase 10 GBYP scientific activities and results by main line of research

3.1 Data mining, recovery and management

The general objective of GBYP data recovery activities is to fill the many gaps existing in several data series currently present in the ICCAT databases, concerning both recent and historical catch or catch by size data, which increase uncertainties in the assessment process. Such activities can also include the recovery of old or recent raw data on BFT ecology or biological parameters.

During Phase 9 there were no contracts related to data recovery, since no relevant datasets were made available for GBYP. However, the GBYP coordination team carried out in-house work in this line related to the study on ABFT growth in farms, which included reformatting and compiling data from stereo-cameras which have already been reported to ICCAT in previous years.

Apart from the continuation of the aforementioned activity, in Phase 10 the in-house work will focus on completing the recovery of all raw data from GBYP funded research activities not yet included in GBYP information system and in designing and built up relational databases to facilitate the management of this information, including the data generated so far from biological sampling, tagging and aerial surveys, as well

as a database integrating the information from stereo-cameras, eBCDs and harvesting operations in BFT farms. All these tasks will be done in close cooperation with the Secretariat Science and Statistics department. In addition, the financial resources assigned to this line will be dedicated to collection and evaluation of relevant data not previously available to SCRS, namely:

- recovery of old electronic tags datasets (University of Bari)
- recovery of recent datasets on catches from Sicilian tuna traps
- recovery of recent electronic tags datasets from other scientists.

3.2 Stock indices: Aerial Survey on Bluefin Tuna Spawning Aggregations

The GBYP Aerial Survey on Bluefin Spawning Aggregations was initially identified by the Commission as one of the three main research objectives of the programme, in order to provide fishery-independent trends on the minimum SSB. Up to now, GBYP has produced a 7-year long series of fisheries independent index of spawning stock abundance based on these aerial surveys over the 4 main spawning areas in the Mediterranean. The index has not been used in stock assessment yet, but it is used in MSE.

However, due to different reasons, this activity has not been developed regularly and has not followed homogenous methodologies and sampling strategies throughout the successive GBYP Phases. The method was finally normalized in 2015, reanalysing all previous datasets, thus providing standardized series of index. Nevertheless, a global revision of the results carried out within Phase 8 showed that no clear patterns in weight and/or abundance among years and areas were discerned yet, and the Coefficient of Variation of the indices remained high, suggesting that there was still room for further methodological improvements. Therefore, several activities aiming at detecting and quantifying potential sources of bias, as calibration surveys, and to improve as much as possible the accuracy of the currently available indices, through refining the sampling strategy and sighting methodology, have been implemented since then.

The aerial surveys in Phase 9 were carried out on the same 4 preferential spawning areas already defined in the previous Phases, using in general the same standardized sampling design and methodology followed from 2017, but incorporating some improvements, such as a change in the Area A in order for it to better fit the real distribution of bluefin tuna spawners and a new refined sighting protocol. In addition, a complete re-analysis of all sighting from 2010 to 2019, including a complete revision of the base data to detect and filter out, for the first time, sightings of juvenile fish has been carried out, in order to provide a new and fully standardized series and remove potential sources of bias. Re-analyses included fine-scale readjustment of the overlap areas and effort tracks, assignment of adult/juvenile categories and recovery of missing data, re-checking the use of bubble windows and creation of parallel datasets to be analyzed independently for cluster size, and then repeated for weight.

Due to the logistical impediments which were in place in the second trimester of 2020 because of the coronavirus crisis, it was impossible to complete all preparatory tasks for the 2020 campaign and therefore the aerial surveys in phase 10 have been cancelled. Consequently, a further field calibration exercise, which was also planned for Phase 10, has been cancelled as well.

Other activities related to fishery independent indices which implied field activities in June, such as feasibility studies for the use of acoustic techniques for developing new BFT indices and for the validation of aerial survey indices were not launched either.

In addition, given that the global revision of the aerial survey data carried out in 2019 has raised various concerns about the representativeness of the index, the Steering Committee recommended that these issues be discussed in-depth before moving forward. Therefore, it was recommended that the BFT Species Group should thoroughly revise GBYP aerial surveys and decide on the conditions for their continuity, as well as determine the research priorities in relation to this and other fisheries independent indices. For that purpose, in order to allow SCRS BFT Species Group to take a well informed decision, an external review of the GBYP Aerial surveys by independent experts will be carried out within Phase 10.

3.3 Tagging activity

The main objectives of tagging activities are the estimation of the natural mortality rates of bluefin tuna populations by age or age-groups and the evaluation of habitat utilization and large-scale movement

patterns (spatio-temporal,), including estimates of mixing rates between stock units by area and time strata, of both juveniles and spawners. This line of research has faced two important problems from the very beginning of the GBYP programme, which have prevented or limited the full achievement of the objectives. One is the very low recovery rate of conventional tags, which impeded the use of these data to estimate reliable mortality rates. Due to this, the GBYP SC decided to cancel the conventional tagging programme in Phase 4 and focus on electronic tagging instead, maintaining only complementary conventional tagging activities by providing tags and tagging equipment to different institutions or organizations, as well as maintaining the awareness and reward campaigns and the database, integrating all the results from recovered tags. The second major problem has been the relatively short time that most of the electronic pop up tags have remained on fish. While the latter problem has already been mitigated by improving the deployment methodology and provision of training to the tagging teams, the problem of the low recovery rate of conventional tags remains.

The specific objective of the 2019 e-tagging campaign was to improve the estimations of the degree of mixing of western and eastern Atlantic bluefin tuna stocks in the different statistical areas over the year cycle, specifically considering the current needs of the MSE modelling process. To this end, the Steering Committee decided to concentrate tagging activities in the North or Norwegian Sea and/or Celtic Sea. Tagging off Ireland was carried out by the Marine Institute in October/ November 2019 with 12 individuals tagged. In Skagerrak tagging was done by the Technical University of Denmark (DTU-Aqua) between the end of August and beginning of September 2019, deploying 15 pop-up electronic tags. In addition, in July 2019, 7 electronic tags were deployed in Olhão, Portugal, within the practical sessions of the GBYP Workshop on electronic tagging deployment methodologies organized in Phase 9 to improve the pop-up tag retention rates. The details have already been given in last year's report. The outputs from this workshop are being used as a reference for developing a new GBYP e-tagging protocol, which will be completed and presented in GBYP phase 10.

The 2019 e-tagging campaigns have been carried out taking into account the conclusions of the aforementioned workshop. Therefore, all the tags have been equipped with reinforced tethers and titanium darts and tagged on board using retention loops. The tags deployed using these reinforced tethers and improved attaching methodologies that have already released, with a mean period on fish higher than that the historical mean in GBYP e-tags, even completing the whole programmed one-year period in some cases, have provided relevant results, such as returns to the same foraging area where the fish was tagged just one year later or confirmation that some adult fish belonging to the eastern stock do not enter the Mediterranean in summer for spawning. Most of tags deployed in Autumn 2019, around 20, have not popped off yet, which confirms the significant increase in the retention rates of GBYP e-tags.

Unfortunately, it must be pointed out that in 2019-2020 the obtainment of data from electronic tags was greatly hindered by a tag transmission problem affecting Wildlife Computer tags Mini PATs produced from the second half of 2018 onwards, about which GBYP was informed in October 2019. The manufacturer recognized that the problem is due to a new type of battery integrated in the tag, which proved to have worse performance than specified, resulting in shorter transmission times, and have replaced the tags in which these transmission failures can be demonstrated. The magnitude of this problem is being currently analysed, and when a global picture be available, once all the potentially affected tags had popped off by the end of 2020, the compensations for these technical failures will be negotiated with the manufacturers.

In addition to field activities, a broad Workshop on bluefin tuna tagging was programmed in Phase 9 as well. It was going to take place in March 2020, but it was postponed at the very last moment due to the quick evolution of coronavirus pandemic. The aim of the Workshop was to reach a broad consensus about the strategic planning of future and the best use of the already available information, with the specific objectives of identifying gaps in movement transitions and life history that can be addressed by strategic electronic tags deployments and drafting terms of reference for conducting joint analyses of the combined tagging datasets. It is envisaged to resume the organization of the workshop once the global situation allows it.

Regarding Phase 10 e-tagging activities, the initial plan was to deploy one batch of electronic tags in the Levantine Sea during the spawning peak, aiming to fill the knowledge gap on the spatial patterns of Eastern Mediterranean populations after spawning, and to deploy the remaining tags in the locations recommended by SCRS experts during the Workshop on tagging that was going to be held in March 2020. At the beginning of 2020 the GBYP SC also decided to take advantage of an offer of collaboration from the "Tag a Giant programme" to deploy for free some e-tags offered in kind or at low cost to GBYP by the University of Cadiz

and by LOTEK company, within the framework of a campaign that this team was going to develop in the Canary islands in March 2020.

These plans have changed due to COVID-19 pandemic, since the GBYP Workshop on BFT e-tagging was postponed and therefore no guidelines were produced, and the envisaged field activities in the Mediterranean and the Canary Islands had to be cancelled. Therefore, taking into account the uncertainty on how the pandemic will progress as well the technical problems affecting WC e-tag performance, the GBYP Steering Committee decided to delay the acquisition of new tags and to deploy in Phase 10 only those already available from cancelled activities or from replacements of previously deployed tags that had failed taking advantage of existing national tagging programmes. To this end, a Call for collaboration in GBYP e-tagging programmes was launched, and after evaluating the offers of 5 MoU to deploy GBYP tags (36 pop-up and 20 archival) in different areas of North Atlantic (Bay of Biscay, Celtic Sea, English Channel, North Sea, Skagerrak and off Newfoundland) have been or will be signed shortly.

Besides the activities carried out under formal GBYP contracts or agreements, GBYP has supported e-tagging activities carried out independently by other institutions, by allowing the use of GBYP RMA in case of BFT casualties during tagging operations and the use of GBYP Argos system account for data transmission. Specifically, the Italian branch of WWF Mediterranean Marine Initiative have been included in the 2019 GBYP list of institutions that can make use of RMA. WWF has recently deployed several satellite tags in the Western Mediterranean which are associated to GBYP Argos system account, so the resulting data will be directly integrated in the GBYP database.

As regards conventional tagging, the GBYP programme has been maintained as a complementary activity, providing logistical support to several institutions. In Phase 9, a total of 293 tags were deployed on 250 bluefin tuna individuals. In total, from the beginning of the Programme, more than 20 thousand bluefin tuna individuals have been tagged, using more than 28 thousand tags of different types.

The GBYP tag awareness and reward policy has also been maintained as in previous phases. As a result, the impressive improvement in the recovery rates detected from the beginning of the GBYP programme has been maintained. Thus, in the year 2019 and the beginning of 2020 a total of 116 and 11 tags have been recovered, respectively. These are slightly fewer than in previous years, but this can probably be attributed to the fact that, on the recommendation of the Steering Committee, from 2014 onwards the GBYP massive conventional tagging programme was cancelled, and hence the number of deployed conventional tags has decreased. It should be stressed that, in the last couple of years, the number of tags recovered and reported from the Mediterranean Sea is higher than any other area. Considering that reported tags from the Mediterranean were almost nil before the GBYP, this is the clear evidence that GBYP tag awareness campaign is producing positive effects.

3.4 Biological studies

One of the core activities of ICCAT GBYP are the so-called Biological Studies, including biological sampling and a series of studies based on the analysis of these samples, as microchemical and genetics analyses to investigate mixing and population structure, with a particular focus on identifying the age structure and the probable sub-populations. The activities in Phase 9 were mostly directed at resolving the Atlantic bluefin tuna population structure and mixing. In particular, one of the most important uncertainties to resolve was related to the understanding of the implications of the new spawning grounds in the Atlantic Ocean (Slope Sea, Bay of Biscay). The priority has been given to mixing analyses to provide accurate information and clear alternative hypotheses to the MSE process. In addition, GBYP has continued with the broad study to determine BFT growth in farms, in connection to ICCAT Rec. 18-02, paragraph 28.

The sampling activity in potential mixing areas for adults, such as the Central Atlantic, Canary Islands and Morocco, has been prioritized with the objective of resolving the population structure. In addition, adult BFT individuals were sampled in the Mediterranean farms, aiming at guaranteeing the availability of enough biological samples to construct representative annual age length keys and for other analyses in a future. In 2019 more than 4400 biological samples were collected, from almost 3000 bluefin tuna individuals. All GBYP samples are stored in the GBYP Tissue Bank, which is maintained by AZTI.

As concerns biological analyses, it was decided to combine both genetic and microchemical analyses on the same sample, whenever possible, to take advantage of the synergies between both approaches to determine the stock of origin.

Regarding otolith microchemistry, new carbon and oxygen stable isotope analyses were carried out in 129 otoliths of Atlantic bluefin tuna captured in the Central North Atlantic in 2016 to determine their nursery area, and the results indicated that these samples were dominated by eastern origin individuals. The comparative analysis with previous Phases suggests that mixing of the two populations occurs at a variable rate, but Mediterranean bluefin tuna may be the principal contributors to the Japanese fishery operating in the central North Atlantic. In addition, for the first time the high-precision secondary ion mass spectrometry (SIMS) was used, with the aim of providing high resolution estimates of oxygen stable isotopes along otolith growth transects. Examination of the relative patterns between individuals indicated substantial variability in environmental histories during the first few months of life. The results support the hypothesis that some individuals are retained within homogenous water masses during early life, while others are exposed to wide variation in water chemistry. Possible evidence of trans-Atlantic migration of adult fish was also recorded in some otolith chemistry profiles.

As concerns the genetic analyses, with the final aim of improving the accuracy of mixing proportions, it was envisaged to generate an improved baseline for the RAD-seq method for origin assignment and expand the number of analyzed bluefin tuna individuals from the Atlantic Ocean. Therefore, an improved baseline for 96 SNP existing traceability tool integrating genome-wide genetic background of the included samples has been generated, considering information on population dynamics complexity. Improved assignment rates were obtained using the new genetic-informed baseline which, together with the original baseline, was used to assign the genetic origin of >2400 samples from feeding aggregations, including 470 newly genotyped samples, completing the mixing map of the Gulf of Mexico and Mediterranean genetic components along the Atlantic. Assignments using the new genetic-informed baseline produced higher assignment rates than those calculated using the original location-informed baseline, both analyses confirming high mixing in Western locations. Besides, when using the genetic-informed baseline, lower proportions of unassigned samples were obtained. The addition of the newly genotyped samples completing the mixing map along the North Atlantic Ocean confirmed previously observed patterns, revealing strong mixing of eastern and western genetic origin individuals in the west Atlantic. Indeed, the Mediterranean genetic profile was majoritarian at every sampled location except for Nova Scotia and Newfoundland. Regarding the population structure of Atlantic bluefin tuna, gene-flow from the Mediterranean Sea into the Gulf of Mexico, most likely through the Slope Sea, was confirmed analyzing RAD-seq data from 535 individuals.

Previous studies supporting the presence of two populations of Atlantic Bluefin Tuna (ABFT) have allowed the development of a traceability SNP panel that assigns individuals to their stock of origin, which is very relevant for ABFT management. Yet, more in-depth analyses have shown that the population dynamics of ABFT are more complex than a pure homing behaviour to the two main spawning grounds (the Mediterranean and the Gulf of Mexico), with feeding aggregates mixing in the Atlantic. First, individuals with Mediterranean genetic background are found within the Gulf of Mexico and, second, the Slope Sea constitutes a genetically intermediate population, which might explain why some individuals cannot be assigned to either population and why some Gulf of Mexico individuals are assigned to the Mediterranean Sea. Initially, these unassignments and misassignments were thought to be a methodological bias, but recent results suggest that they might be due to a more complex population structure in ABFT that is not considered by the genetic assignment method. Since the current mixed stock model used for management purposes does not acknowledge that individuals from both stocks can interbreed, the consequences of doing so should be evaluated. In addition, the contribution of the individuals born in the Slope Sea to each of the two main stocks is not clear as there is no way to differentiate them genetically. Thus, in order to better understand the migration and reproductive behaviour of ABFT and to develop an improved traceability panel that takes these new findings into account, additional analyses are envisaged.

Other analyses included larvae identification in the Bay of Biscay and a feasibility study on the use of larvae from larval index surveys for genetic analysis. A search was performed for ABFT larvae in samples collected in past surveys in the Bay of Biscay because recent studies demonstrated through the presence of early larvae that ABFT spawns, at least occasionally, in this area. Therefore, a total of 7,017 larvae were checked from 368 zooplankton samples from previous surveys in the region and one larva identified genetically as bluefin was found. This sample was collected in August 2009 west of Santander in a mean sea surface temperature of 21.6°C and a mean sea surface salinity of 34.88. Since this larva could not have been

transported in any way into this area from the Mediterranean Sea spawning ground, it provides further evidence of BFT spawning in this region. However, further studies should be conducted, based on plankton hauls specifically designed to target tuna larvae, to evaluate the importance of this new spawning ground.

The feasibility study on the use of larvae from current larval surveys in the Balearic Sea for genetic analysis showed that larvae preserved in Cytoscan are not suitable for the genetic analysis, while larvae preserved in pure Ethanol were suitable. Finally, a total of 339 bluefin tuna larvae from 22 stations sampled in 2018 and 2019 surveys following this latter preservation methodology were genetically analyzed within this study. It could be concluded that thanks to these methodological improvements in samples preservation and handling, larval surveys could provide useful material for genetic analyses, even for those studies which require a high number of larvae, such as the Close Kin approach.

Regarding ageing related analyses, in Phase 9 a broad otolith calibration exercise has been carried out by the ageing group of experts of the SCRS BFT species group (6 laboratories) and a new and more complete otolith reference collection has been created. In addition, the reading of a set of 2,000 otoliths has been successfully finished by Fish Ageing Services The readings show a high coherence, since a single more prominent cohort can be followed consistently along the years and the resulting length at age data also show a coherent growth curve. However, due to some systematic bias in these results in relation to estimations from other experts detected during the calibration exercise, the final revision of these data will be carried out within Phase 10 before using them for management purposes.

There were two workshops related to biological studies planned to be held within the last months of Phase 9, but both were cancelled/postponed due to the COVID-19 outbreak. One was a larval index surveys coordination workshop, aiming at facilitating coordination between different CPCs' national studies, while the second was a workshop on Close Kin methodology, aiming at providing insights into new achievements of the method and evaluating its potential use on Eastern BFT stock.

The plan for biological studies in Phase 10 is to continue with sampling in the Atlantic Ocean in order to resolve population structure and to sample in the Mediterranean, as well to contribute to the update of the ALK. The analyses will be focused on providing accurate and reliable estimations of mixing rates between two BFT stocks. In particular, it is planned to further clarify the Bluefin Tuna genetic population structure by understanding the phenomena that are driving genetic differentiation despite gene flow, to develop a cost-effective and reliable SNP genotyping tool for tracing movements and estimating gene-flow between management areas, to improve the traceability panel and to continue monitoring mixing throughout foraging areas using alternative baselines and alternative markers. In addition, in relation to aging, it is envisaged to perform a new calibration of the otolith age estimates provided in Phase 9 by FAS, and to perform an analysis of the otolith edge type deposition and marginal increment along year cycle. In addition, further ichthyoplankton studies, including sampling of ABFT larvae in the Bay of Biscay and provision of Balearic Sea ABFT larvae for genetic studies, will be carried out within Phase 10.

3.4.1 Study on BFT growth in farms

Following the successful preparatory work finished in Phase 8, the activity in Phase 9 continued with the implementation of field and desk work for database generation, including preliminary and partial data analysis. With that purpose, contracts were signed with farms and/or research institution to carry out studies in 5 representative areas: Portugal, Spain, Malta, Croatia and Turkey. Among these, it was possible to perform broad tagging experiments only in two farms, in Portugal and Croatia. Therefore, in addition to the individual growth approach required by Rec. 18-02, aiming to provide comparable growth rate estimations among different areas, a common methodology based on the intensive monitoring of one or two cages in each farm, containing the widest possible caged fish length distributions, has been implemented in all the areas. The monitoring includes, in addition to the initial estimation of the length distribution in the cage through the official measurement with stereo-cameras, bimonthly or seasonal additional measurements with stereo-cameras, a daily record of environmental parameters and food supply and the record of real length and weight data from all the fish in the monitored cage at harvesting. This will for the determination of seasonal growth in length by size group through Modal Progression Analyses, the relation of these growth rates with environmental parameters and the determination of the final gain in weight by size group. These studies will be completed within Phase 10, when all the fish in the monitored cages are harvested.

As already mentioned, the tagging of part of the fish in the monitoring cages, in order to get individual growth data, was performed on adult fish in Portugal and on juveniles in Croatia. The study in Portugal was affected by a high mortality of tagged fish and a loss of great number of identifying tags, which hindered the obtention of reliable results. Therefore, this study is being repeated within Phase 10. The tagging study in Croatia initiated in Phase 9 with the successful tagging of 202 juveniles, with almost null mortalities after tagging, and which also includes the intensive and continuous monitoring along the whole farming period described in the previous paragraph, is being conducted by now without any problem. The final data will be available only in 2021 when the fish will be harvested.

In parallel with field activities, in-house work to contribute to growth in farms studies was initiated at the ICCAT Secretariat through close collaboration between the Department of Research and Statistics and the GBYP Coordination team. It has been oriented to the formatting and consolidation of data reported from stereo-cameras to ICCAT (2014-2018). This first step will enable the creation of an operative relational data base, linking data on estimated initial lengths and weights from stereo-cameras at caging with measures of real final weighs and lengths at harvesting from e-BCD system, as well VMS data. It will facilitate broad studies on the growth of caged fish in all the areas where BFT farming takes place along Phase 10 and, at the same time, provide crucial information for stock assessment (length distributions of the captures of purse-seine fisheries).

The combination of all the information on growth rates generated by these different approaches with the information about farming methodologies gathered through the ad hoc questionnaire submitted by all the ABFT farms and the direct detailed monitoring of environmental parameters and food supply in selected cages will also allow for the exploration of the causes of potential variability among growth rates in different regions at several time and space scales.

Following activities to be developed within Phase 10 will include the continuity of experiments initiated in 2019, whenever necessary, as well as the development of new pilot studies, using acoustic and IAS techniques, allowing accurate (even on a daily basis if required) measurement of the growth of caged fishes, both in length and weight. In addition, in-house activities on the consolidation of data from stereo-cameras and the creation of a relational database will continue. The initial plan was to develop these studies in two areas, one in the Mediterranean and one in the Atlantic, specifically in Morocco. Finally, despite the fact that the preparatory work had been already carried out over the first quarter of 2020, due to the coronavirus outbreak the pilot study in Morocco has had to be postponed until 2021.

The global analysis of all the data generated within the aforementioned GBYP studies will be carried out in close coordination with the SCRS subgroup on growth in farms, which will take care of elaborating a unique and agreed response to the Commission.

3.5 Modelling approaches

The modelling programme addresses the GBYP general objective 3, which is "Improving assessment models and providing scientific advice on stock status through improved modelling of key biological processes (including growth and stock-recruitment), further developing stock assessment models including mixing between various areas, and developing and use of biologically realistic operating models for more rigorous management option testing". The modelling activities started in Phase 2, and very soon it became evident that this line of study had greater importance than perceived at the time when the GBYP was conceived and that the amount of effort for this activity should be much larger than initially considered. In addition, the MSE process embarked upon by ICCAT has been an important initiative which has represented a significant investment of time and resources by the Commission, CPCs and the scientists involved.

In Phases 9 and 10 the contract for modelling approaches was again awarded to Dr. Tom Carruthers (Blue Matter Science, Canada), who initiated the work on MSE and modelling in 2014. The 2019 contract saw the final adjustments to model configuration and data weighting. Over the course of 5 revisions, including more than 100 individual changes to the input data and model, an estimation model was developed in November and presented in December 2019. This model, which could pass the necessary red-face tests, spans the range of uncertainties of the reference set operating models and recreates the scenarios of the robustness set operating models. A series of additional tasks were completed, such as data processing checks, engaging in dialogue with data providers to confirm that the data are processed correctly for M3 OM conditioning, updating Trial Specifications document and M3 model to version 5, coding and fitting of new reference and

new robustness set OMs, fitting interim grid OMs with sensitivity runs, updating ABT-MSE framework, fully debugging and adding M3-ABTMSE check mode, checking and implementing basis for transforming biennial estimates of variance and correlation in recruitment, updating OM report to include estimated movement probabilities, observed tag recaps and recruitment, adding latest interim grid OMs and robustness and further performance statistics OMs to the package, and drafting SCRS papers on results for multiple alternative Master indices, simple model-based CMP and fully defining protocols for CMP tuning.

All deliverables were completed, with the exception of the updated Shiny App which requires finalized reference set and robustness set operating models and CMPs. In addition to the contracted tasks, more than 100 changes were made in the model and data, following requests from the Bluefin Tuna Working Group. The MSE framework is complete, but all components downstream of the Management Procedures and the Management Objectives are still not finalized.

The plan for Phase 10 is to ensure the OM scenarios agreed by the CMG in 2016 and revised in 2017, 2018 and 2019 by the Technical MSE Group (formerly CMG) and the MSE BFT Group, can be run, that third parties can use the OM to evaluate candidate MPs (CMPs) of their own specifications, and to provide a set of agreed summary statistics that can be used by decision makers to identify the MP, including data and knowledge requirements, that robustly meets the management objectives.

In addition to contracting the MSE expert, GBYP has been continuously providing its support to the BFT MSE Technical Group (formerly GBYP Core Modelling and MSE Group), whenever needed, by covering the travel expenses of the chair and key members for participating in MSE related meetings.

4. Outline of GBYP Phase 11 proposal

a) Data recovery: Recovery of further data sets relevant for improving BFT management
b) Fishery independent indices: if recommended by SCRS BFT Species Group, eventual development of new series of aerial surveys according to the conclusions from the global external review carried out in Phase 10, feasibility studies for the development of alternative fishery independent indices, and application of habitat models to standardize fishery independent or dependent indices
c) Tagging: Support to conventional tagging and tag awareness activities; development of electronic tagging campaigns, prioritizing areas according to assessment needs
d) Biological studies: Maintenance of GBYP tissue bank, development of biological sampling and analysis programme aiming to ensure availability of samples and generation of basic data to cover research needs derived from SCRS recommendations; pilot study combining image analyses and acoustic techniques to determine growth in farms in Atlantic waters (Moroccan farms); implementation, within ICCAT DB system framework, of relational databases integrating data from GBYP (biological analysis, tagging, data from stereocamera systems and harvesting operations); workshop on biological sampling standardization and coordination; if recommended by SCRS BFT Species Group, the implementation of Close Kin methodology for the assessment of Eastern BFT stock, following the conclusions from the workshop on Close Kin methodologies held in Phase 10.
e) Modelling: Continuous GBYP support to the development of the ICCAT BFT MSE process (funding developers and BFT MSE technical group workshops)

Total envisaged budget € 1,500,000**

***Tentative budget subject to revisions derived from BFT SG discussion and budget availability*

Bibliography

Alemany F., Tensek S., Pagá García A., 2019. ICCAT Atlantic-Wide Research Programme for Bluefin tuna (GBYP) Activity report for Phase 8 and the first part of Phase 9 (2018-2019). ICCAT Col. Vol. Sci. Papers. 76(2): 521-566.

Table 1. Approved budget of GBYP Phase 9 and 10.

Item	Phase 9	Phase 10
Coordination	€227,000.00	€375,000.00
Data Recovery	-	€25,000.00
Aerial Survey	€535,775.00	€612,000.00
Biological Studies	€710,000.00	€620,000.00
Tagging	€177,500.00	€218,000.00
Modelling	€99,725.00	€150,000.00
Total	€1,750,000.00	€2,000,000.00