ICCAT ATLANTIC-WIDE RESEARCH PROGRAMME FOR BLUEFIN TUNA (GBYP) ACTIVITY REPORT FOR PHASE 12 AND THE FIRST PART OF PHASE 13 (2022-2023)

F. Alemany[1], S. Tensek[1] and A. Pagá García[1]

SUMMARY

The ICCAT GBYP Phase 12 was implemented between 24 March 2022 and 23 July 2023. Phase 13 was initiated on 1 May 2023, with a planned duration of one year, therefore temporarily overlapping with Phase 12. As in previous years, the GBYP programme has promoted and funded several activities in the following lines: (a) data management, (b) biological studies, (c) stock abundance indices, (d) tagging, including awareness and rewarding activities and (e) further steps of the modelling approaches. The present report summarizes the final results of the activities carried out in Phase 12 and describes the activities initiated in Phase 13, and their preliminary results, if available.

RÉSUMÉ

La phase 12 du GBYP de l'ICCAT a été mise en œuvre du 24 mars 2022 au 23 juillet 2023. La phase 13 a été lancée le 1er mai 2023, avec une durée prévue d'un an, recoupant donc temporairement la phase 12. À l'instar des années précédentes, le Programme GBYP a encouragé et financé plusieurs activités dans les domaines suivants : (a) gestion des données, (b) études biologiques, (c) indices d'abondance des stocks, (d) marquage, y compris activités de sensibilisation et de récompense, et (e) nouvelles étapes des approches de modélisation. Le présent rapport résume les résultats finaux des activités menées dans le cadre de la phase 12 et décrit les activités entreprises au cours de la phase 13, ainsi que leurs résultats préliminaires, si disponibles.

RESUMEN

La fase 12 del GBYP de ICCAT se implementó entre el 24 de marzo de 2022 y el 23 de julio de 2023. La fase 13 se inició el 1 de mayo de 2023, y tiene una duración prevista de un año, por lo tanto, se solapa temporalmente con la fase 12. Como en años anteriores, el GBYP ha fomentado y financiado diversas actividades, en la siguiente línea: (a) gestión de datos, (b) estudios biológicos, (c) índices de abundancia del stock, (d) marcado, lo que incluye actividades de concienciación y recompensas y (e) más avances en los enfoques de modelación. El presente informe resume los resultados finales de las actividades llevadas a cabo en la fase 12 y describe las actividades iniciadas en la fase 13 y sus resultados preliminares, si están disponibles.

KEYWORDS

Bluefin tuna, ICCAT, historical data, biological analyses, tagging, genetics, ageing, microchemistry, aerial survey, modelling, Mediterranean Sea, Atlantic Ocean

1. Introduction

1.1 Historical background

The Atlantic-Wide Research Programme for Bluefin Tuna was officially adopted by the ICCAT Commission in 2008, endorsing the SCRS Chair's report on Bluefin Tuna Research Priorities and Potential costs. In 2009 the SCRS advised the Commission that, in order to substantially improve the scientific advice, such program would focus on the improvement of basic data collection through data recovery, understanding of key biological and ecological processes, and improvement of assessment models to provide scientific advice on stock status.

[1] ICCAT, GBYP – Calle Corazón de Maria 8, 6ª – 28002 Madrid (Spain)

During the Commission Meeting in 2009, a number of Contracting Parties expressed a willingness to make extra-budgetary contributions to such a Programme, with a view towards initiation of activities related to different priorities: Programme coordination, data recovery, aerial surveys and tagging design studies, with additional research activities to be undertaken in the following years. The provision to accept additional contributions from various entities and private institutions or companies was also agreed.

GBYP (Grand Bluefin Tuna Year Programme) was then adopted as official acronym of the research programme. Given that budgetary contributions would be made annually the Programme has been implemented by annual Phases. To facilitate its coordination and management a post of Programme Coordinator was created, and a Steering Committee (SC) was set.

It was initially envisaged as a 6-year programme, but in 2014 the GBYP Steering Committee and the SCRS (documents SCRS/2014/194 and SCI 005/2014) recommended extending the GBYP activities up to 2021 and this proposal was endorsed by the Commission during its November 2014 meeting, along with the SCRS report. A new plan for the GBYP activities to be done during these additional years was approved along with the extension. Consequently, the donors maintained their contributions, allowing the continuity of the programme. In its report for the biennial period 2020-2021, Part 2 (2021), adopted in the 27th regular meeting of the Commission, the SCRS explicitly requested further funding of the GBYP for the period 2022-2026.

From 2015 GBYP is being complemented by a twin programme, the BTRP, funded by NOAA-NMFS and addressed to USA research teams, which focusestheir research activities on the western Atlantic Ocean.

1.2 Objectives

At the beginning of the programme the GBYP Steering Committee defined as the main objective of the GBYP the improvement of the knowledge and understanding of the Atlantic bluefin tuna (*Thunnus thynnus*) stocks and populations. Aiming at the achievement of this strategic objective, a series of general objectives was set considering the priorities initially stated by SCRS (data collection, understanding of key biological and ecological processes and assessment improvement). These broad objectives have been maintained throughout the program, but along the successive phases they have been adapted to the evolution of the "state of the art" as regards scientific knowledge on bluefin tuna, in order to better match SRCS research needs and Commission recommendations.

Therefore, the current general objectives of GBYP program are:

- Improve basic data collection.
- Improve understanding of key biological and ecological processes.
- Improve assessment models and provision of scientific advice on stock status.
- Enhance the coordination between GBYP activities and the monitoring and research activities on BFT carried out by other institutions, both at national and international level.
- Contribute to the implementation within ICCAT Secretariat of new BFT information management systems.

In addition, a general objective is to consolidate the new knowledge generated in the different lines of research developed throughout the last decade, carrying out whenever necessary global reanalyses of available data and synthesizing the results generated in previous phases, in order to provide sound conclusions that can be directly applied to improve stock management.

In relation to each of these broad objectives, the specific objectives set for GBYP Phase 12 were:

a.1. Make available to SCRS further information on BFT spatial patterns relevant for stock assessment and MSE modelling, by compiling and incorporating to ICCAT databases relevant data sets.
a.2. Optimize BFT biological sampling programs, ensuring that sampling activities carried out by CPCs and those funded by GBYP are complementary and collect representative biological samples, in such a way that their analysis can improve the stock management input needs/requirements.
b.1. Enhance the information available on spatial distribution and mixing.
b.2. Provide SCRS with updated and reliable biological parameters and age/length keys.
b.3. Evaluate the feasibility and elaborate a realistic work-plan proposal for the implementation of the close-kin mark-recapture approach to EBFT
c.1. Contribute to updated, improved and new fishery dependent and independent indices of abundance.
c.2. Support the development and implementation of BFT Management Strategy Evaluation (MSE).

c.3. E-BFT stock 2022 assessment.
d.1. Contribute to the implementation of an internationally coordinated BFT sampling system.
d.2. Promote the joint analysis of broad datasets integrating data from different CPCs research teams and GBYP.
d.3. Develop and promote the application of standardized BFT populations monitoring and sampling, as well as data analytical methods.
e.1. Contribute to the design and implementation, in close coordination with ICCAT Secretariat Research and Statistics departments, of an Information System on BFT biological data, that will integrate relational databases including all relevant available information from GBYP and that provided by CPCs research teams.
e.2. Contribute to the design and implementation, in close coordination with ICCAT Secretariat Research and Statistics departments, of an Information System on electronic tags data, integrating etags data sets from ICCAT and CPCs e-tagging programmes.

1.3 Programme management and financial aspects

The GBYP programme development is supervised by a Steering Committee, which has the role to guide and supervise its implementation. It is composed by the SCRS chair, W-BFT rapporteur, E-BFT rapporteur, one external member and the ICCAT Executive Secretary, which can be substituted by his deputy. The Steering Committee is regularly informed and consulted by the GBYP Coordinator for all relevant issues. The Steering Committee meets not less than once a year, to verify the activities done, refine and propose the follow-up of the Programme, and adopt the budget.

The GBYP coordination team carries out the day to day tasks related to the implementation of the project, including the elaboration of the calls for subcontracting different types of activities and for Expressions of Interest to collaborate with some of the GBYP lines of research, the drafting of contract and Memorandum of Understanding proposals, supervising the reports received from contractors or collaborating institutions, organizing GBYP related meetings and workshops, taking care of the regular reporting on the GBYP activities to the SCRS relevant groups and the elaboration of the final annual global and executive reports presented to the SCRS Plenary and to the main donor, the EU.

Furthermore, the GBYP coordination team participates, or provides scientific support whenever requested, in national or international initiatives which are potentially able to increase the effectiveness of the GBYP and the achievement of its objectives. For example, since 2010 the GBYP coordinator has been part of the Evaluation Committee of the NOAA BTRP and has participated regularly in the meetings of the EU Regional Coordination Group on Large Pelagic since its creation.

The GBYP is funded by voluntary contributions of CPCs and other entities, as Chinese Taipei. Among CPCs, EU provides 80% of total budget. In addition, several private or public entities also provide few additional funds or in-kind support. The budget is set annually, by phase. The evolution of the total budget throughout the Programme, by type of activity, is shown in **Table 1** (in euro).

It must be pointed out that this annual and variable funding scheme, relying on voluntary contributions, instead of a multi-year and more stable funding system, is one of the major problems for GBYP, because this fact makes difficult a mid- and long-term planning of the activities, which would be for sure more efficient. The GBYP Steering Committee and the SCRS have recommended several times the adoption of a more stable funding system, but all proposals submitted so far by the ICCAT Secretariat or some CPCs to the Commission (i.e.: scientific quota, CPCs contribution proportional to quota, etc.) were discussed but they were never approved. The uncertainties linked to the funding at each Phase are creating operational problems since the beginning of the programme, because it is difficult to plan all activities and provide all necessary contracts when the effective funding for a given Phase is confirmed only at the very end of the previous one. This fact implies continuous attention to the effective budget availability at each step of the programme by the Coordination team and Steering Committee and the impossibility to operate with multi-year contracts for multi-year activities.

The general information about GBYP activities and its results from the very beginning of the programme till nowadays, as well on budgetary and other administrative issues, is available from ICCAT GBYP webpage (https://www.iccat.int/GBYP/en/). All the relevant documents related to the programme development, including final reports of every activity and derived scientific papers, annual reports to SCRC and European Union, as well GBYP workshops or Steering Committee meetings reports, are also easily available therefrom.

2 Budget

The twelfth Phase of the ICCAT GBYP officially started on 24 March 2022 following the signature of the Grant agreement for the co-financing of the ICCAT GBYP Phase 12 (101091166) by the European Commission. Initial duration of the Phase was one year, but it was extended for 4 months, thus officially ending on 23 July 2023.

Phase 12 was amended in March 2023, in order to extend the duration of the agreement and to rearrange the available budget to better match the updated SCRS workplan. The main motivation for extending the Phase was the need to hold the three scheduled workshops, which were postponed first due to Covid19 and then some of them were further delayed because of the tight SCRS meeting agenda, which prevented to organize the last one until beginning July 2023. In addition, it was extended to be able to carry out new studies in relation to the feasibility study on the application of the Close Kin Mark Recapture approach to the evaluation of the BFT Eastern stock, which were identified as priority by SCRS at the end of 2022.

It is worth to mention that the GBYP Phase 12 overlapped with Phase 11, which was also extended mainly to deal with delays derived from COVID 19 pandemics, for more than five months (24 March 2022 - 1 September 2022), and has also overlapped for almost three months with Phase 13 (1 May 2023-23 July 2023), which necessarily had to start in May 2023 to allow the organization and development in time of the GBYP aerial surveys that had to be funded under Phase 13 budget. It has made a bit more complex the GBYP programme management, but it has been possible to develop in parallel the different phases without major problems, since each phase has a well-defined work-plan and budget, and hence every cost can be assigned univocally to the activities detailed in the respective Grant Agreements.

A report of the GBYP activities in Phase 12 up to September 2022 was provided to the BFT Species Group (SCRS/2022/168) and the SCRS (SCI 30B/2022 and SCI 113/2022). The final report of Phase 12 activities will be submitted to SCRS in September 2023, and presented within the SCRS 2023 Plenary meeting.

In Phase 12, the budget had the following funders when the proposal was presented (in order of contribution already received):

European Union	1,200,000.00 €
Morocco	57,882.26 €
Tunisia	50,109.54 €
Japan	49,686.39 €
Türkiye	40,626.86 €
Algerie	29,170.26 €
Norway	24,287.66 €
Canada	21,327.38 €
Libya	12,917.23 €
Korea	3,525.11 €
Iceland	3,172.60 €
Albania	2,996.34 €
Chinese Taipei	2,000.00 €
China	1,797.80 €
United Kingdom	500.57 €
TOTAL	**1,500,000.00 €**

Phase 13 of ICCAT GBYP officially started on 1 May 2023 following the signature of the of the Grant agreement for the co-financing of the ICCAT GBYP Phase 13 (101133291) by the European Commission. In Phase 13 the budget has the following funders, although some amounts have only been committed by CPCs and not yet received:

European Union	900,000.00 €
Morocco	66,280.30 €
Japan	55,782.93 €
Tunisia	47,258.00 €
Türkiye	46,575.34 €
Libya	45,643.84 €
Algerie	36,239.20 €
Canada	20,529.68 €
Norway	19,000.00 €
Albania	4,719.17 €
Iceland	4,012.64 €
Korea	3,958.90 €
TOTAL	**1,250,000.00 €**

Further amounts were residuals of previous GBYP Phases, and they were used for better balancing the EU contribution and for compensating costs which were not covered by the EU funding in the various Phases. Additional eventual residuals from the amounts provided in Phases 12 and 13 or further contributions from other CPCs will be used for the following Phases of GBYP. It should be noted that some contributions for the current and previous GBYP Phases are still pending from several ICCAT CPCs.

3. Programme Coordination in Phase 12

3.1 Steering Committee

The Steering Committee has been composed by the SCRS chair (Dr. Gary Melvin; Dr. Craig Brown), the Western BFT rapporteur (Dr. John Walter), the Eastern BFT rapporteur (Dr. Enrique Rodríguez Marín), the ICCAT Executive Secretary (Mr. Camille Jean Pierre Manel) and the external expert. The contract for the external member of the Steering Committee was signed, following the decision of its *ex officio* members, taken considering her expertise in lines currently crucial for the SCRS BFT group as MSE processes and CKMR studies, with Dr. Ana Parma, researcher at the Centre for the Study of Marine Systems – CONICET (Argentina).

During the Phase 12, one SC meetings have been held, in September 2022. Other decisions have been taken via email, following the regular correspondence held between the GBYP Coordinator and GBYP SC members for all relevant issues.

3.2 Coordination Team

The Coordination Team has been composed by the GBYP Coordinator (Dr. Francisco Alemany), the Assistant Coordinator (Mrs. Stasa Tensek) and the Database Specialist (Mr. Alfonso Pagá). In 2023 up to July it also included an Administrative Assistant (Dr. Erin McClelland). It should be pointed out that the ICCAT Secretariat provided technical and administrative support for all GBYP activities on a daily basis.

3.3 Project management activities

During Phase 12, a total of 3 calls for tenders and 6 official invitations have been released, which have resulted in a total of 10 contracts awarded to various entities (**Annex 1**). In addition, one call of expression of interest for collaborating with GBYP etagging program was published, which resulted in 8 memorandums of understanding signed.

Other routine project management activities have been the actions related to GBYP Research Mortality Allowance, the Tag awareness and reward program, the regular communication with the Steering Committee members and the updating of the GBYP web page.

Regarding RMA, during 2022 the Research Mortality Allowance was used for covering the incidental death of 123 specimens of bluefin tuna, which equals to a total of 2193 kg, reported through 17 RMA forms. Considering the number of specimens, most of these correspond to sampling activities, while considering the weight, the most correspond to incidental deaths due to electronic tagging activities.

In addition to the coordination tasks related to activities developed under these contracts or agreements and other day to day communication tasks with different stakeholders, the GBYP coordination team has participated in all SCRS meetings focused on bluefin tuna:

- Eastern Atlantic and Mediterranean bluefin tuna data preparatory meeting (including BFT MSE) (Online, 18-26 April 2022)
- Intersessional meeting of bluefin tuna MSE technical sub-group (online, 3-6 May 2022)
- Eastern Atlantic and Mediterranean bluefin tuna stock assessment meeting (Madrid, Spain, hybrid meeting, 4-9 July 2022)
- Second intersessional meeting of the bluefin tuna technical subgroup on MSE (Online 5-9 September, 2022)
- Bluefin tuna Species Group Meeting (19-24 September 2022)
- Standing Committee on Research and Statistics (SCRS) meeting (Madrid (Spain)/Hybrid 26-30 September 2022)

Moreover, the GBYP coordination team organized three workshops:

- ABFT Larval Indices Workshop (Palermo, 7-9 February 2023)
- Workshop on ABFT CKMR including Biological Sampling Coordination (Madrid, 14-16 March 2023)
- Workshop on ABFT Electronic Tagging (Madrid, 4-6 July 2023)

Furthermore, the GBYP Coordinator participated in person in the following meetings:

- ICES course on CKMR methodology, and meeting with CKMR experts for developing the workplan proposal for CKMR implementation on E-ABFT (San Sebastian, 20-30 November 2022)
- Meeting with Fuentes farms representatives (Murcia, 12-13 April 2023)
- European Tracking Network EU COST action final symposium and first workshop of STRAITS (Strategic Infrastructure for improved animal Tracking in European Seas) EU HORIZON project (Izmir, 1-3 May 2023)
- ICCAT ROP training course (Valencia, 16-18 May 2023)
- Meeting with farms representatives (Barbate, 18-19 May 2023)
- International Conference on Fish Telemetry (Séte, 12-16 June 2023)

GBYP Coordinator also gave talks within the EU funded InterDiSummer School (Interdisciplinary Ocean Transformation for Early-Career Ocean professionals (Palma de Mallorca, 29 May – 2 June 2023) and the ICCAT ROPs Training Course (Oliva, 3-5 April 2023). He also participated online in the Regional Coordination Group Large Pelagics (RCG LP) 2023 meeting (Malta,26-28 June 2023).

4. Activities

The Phase 12 and 13 activities, adapted to the current SCRS research needs and Commission requests, were structured considering the main lines of research established since the beginning of the programme, i.e. data recovery and management, biological studies, tagging, stock abundance indicesand modelling, All activities carried out throughout the GBYP Phase 12 and the beginning of Phase 13, as well their final or preliminary results and the related coordination activities, are summarised in this report.

In general, most of the activities were successfully implemented according to the planned timetable. An extension of the GBYP Phase 12 was requested in order to be able to hold the three planned workshops and a special study on epigenetics to inform on the feasibility of the application CKMR approach on ABFT. All three workshops were finally scheduled for 2023, when taking into account the evolution of the COVID-19 pandemic it was considered safer to hold the in person/hybrid meetings. Then, the tight schedule of SCRS meetings to be held in ICCAT Secretariat obliged to fix the last one in July 2023.

4.1 Data recovery and management

This activity involves the compilation, storage and review of all relevant scientific information, original and processed, produced by or received in GBYP, including the data update and the errors correction in the databases. It regularly provides updated and verified information to the SCRS and the Secretariat.

Following the strategic shift initiated in Phase 10, most of efforts in this line have been directed to the development of information systems allowing the proper storage and analysis of the data from GBYP funded research activities or other data relevant for BFT management not yet included in current ICCAT databases, and hence to make the better use of the huge amount of data generated within previous Phases. These activities, initiated in previous phases, have mainly consisted of in-house desk work. In the case of the biological data information system, the work has been focused on data modelling and data warehouse, progressing in the creation of structures to facilitate the data sharing between different CPCs research teams and ICCAT science programs and to proper data warehouse of both the biological data and the results from the analyses carried out on these samples. Moreover, significant progress has been made on the definition and concentration of data types, data needs and uses. Simultaneously, a review has been carried out, of the condition of the samples collected in the previous years and its recording in the inventory.

In addition, the project ETAGS initiated in Phase 11 was continued in close collaboration with the ICCAT Secretariat Statistics Department, for developing an integrated electronic tagging management system capable of managing the data from all the electronic tags released by ICCAT, or provided by CPCs scientific teams, in all

ICCAT managed species. The rationale behind this project is that existing and future raw data sets from electronic tags, together with all the associated metadata, will be much more useful to the ICCAT scientific community if all the information is validated, stored and managed by means of a centralised relational database. For this purpose, the follow-up contract was signed with Dr. Chi Hin Lam (Big Fish Intelligence Company Limited), who has already developed a system to manage and analyse electronic tags data and who was already awarded the contract in GBYP Phase 11. Dr Lam was contracted to adopt the existing system to ICCAT needs and provide necessary support and training on platform installation and use of the tools. The activities in Phase 12 included:

- Full implementation of multiple-tracks support and improvements in database operations
- Extended ETUFF support of /tag files importation from Lotek Wireless and Microwave Telemetry
- Continued support of eTUFF uploads to ETAGS database
- Streamlined data ingestion work

Given the complexity of the overall project, including combination of various technologies needed and large amount of data in the inventory, the project will probably be continued within future Phases, especially considering the task related to customization of components based on new data access patterns.

4.2 Fishery independent stock abundance indices (Aerial and Larval Surveys)

ICCAT GBYP Aerial survey on bluefin spawning aggregations (AS) 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. However, due to different reasons, as budget and logistic limitations and different opinions about the best sampling strategies between successive SC members, this activity has not been developed regularly and has not followed homogenous methodologies and sampling strategies from the very beginning. Moreover, the AS has faced numerous logistical challenges, which have resulted in changes in survey design and data processing to standardize methodologies and improve the accuracy of the index.

In 2019, all historical GBYP aerial survey data were re-analysed for all the areas and years in a homogeneous way, correcting some errors that were not detected before and also introducing some methodological improvements in the data analysis process, resulting in new more accurate and fully standardised index time series. However, the new index time series exhibited substantial differences in relation to prior time series, and still showed a high interannual variability between and within areas, which raised new concerns about the estimation procedures and the overall efficacy of the survey. Consequently, the SRCS BFT Group recommended to carry out an in-depth revision by external independent experts. Such revision was performed in 2020 by two recognized experts, including one of the original developers of the analytical methodology used in these surveys, who detected some inconsistencies and presented several recommendations for its improvement. One of these recommendations was to start moving to digital observing and counting systems to substitute human observers-based system, and another was to extend, if possible, the surveyed areas. So, in 2021 a pilot aerial survey was carried out in the Balearic Sea area, aiming at evaluating the feasibility of using digital systems for the monitoring of BFT spawning aggregations and its accuracy and precision, as compared to the classic human observers-based system. Finally, a global reanalysis of the whole time series was carried out, applying both the design-based approach used from the beginning of the GBYP aerial surveys, but also exploring a new model-based approach aiming at overcoming the potential impact of interannual environmental variability on BFT spawners distribution and index accuracy. In 2022, within Phase 11, the aerial survey was conducted in the core areas of the Western and Central Mediterranean Sea following the standard human observers-based methodology.

4.2.1 GBYP Aerial survey activities in Phase 12

Within Phase 12 a new reanalysis of the available dataset, including the more recent data from 2022 surveys, has been carried out following a design-based analytical approach, the one used from the beginning of the project, to update the index time series currently used for BFT Eastern stock management. In addition, following the recommendation from the external independent experts and the requests from SCRS, further efforts have been focused in the application of an improved model-based approach, by considering a complete set of environmental variables driving the BFT spawners spatial and temporal distribution in the spawning areas, to produce a more reliable and accurate aerial index time series for Western and Central Mediterranean that could be used in a future (after the reconditioning of the MSE operating models), to improve the stock management. To this end, a contract was provided to a temporary association of purpose formed by the University of St. Andrews (CREEM) and the Spanish Institute of Oceanography (IEO-CSIC). CREEM team has been identified as a leading institution in the design and analysis of distance sampling surveys, given that they developed the software used for these purposes (DISTANCE) and has already conducted the complete re-analyses of GBYP aerial survey data up to 2021. The IEO-CSIC team working on tuna larval ecology in the Balearic Islands Centre, which provides the larval index for BFT Eastern stock management, was acknowledged to have a unique and recognized experience in the modelling of the Eastern stock Atlantic bluefin tuna spawning habitat.

Therefore, in Phase 12 the aerial survey data collected in 2022 were analysed in order to estimate biomass and abundance of Bluefin tuna (BFT) in the Mediterranean Sea in the three surveyed blocks: A, C and E. Two approaches were undertaken: 1) Design-based analysis of visual aerial surveys to continue time series of abundance/biomass estimates of BFT in the Mediterranean, updating it with 2022 survey data and 2) Model-based reanalysis of the available 2017-2022 data set, considering a complete set of environmental variables, aiming to understand which covariates drive seasonal and regional changes in BFT abundance and biomass. This allow to develop a spawning habitat model that will be used for standardizing the index time series accounting for the interannual variability of observed abundances in the surveyed area attributable only to changes in the hydrographic scenario and not to real variation in spawning stock abundance.

The results from the 2022 surveys showed that most sightings were made in block A, resulting in the highest estimated encounter rates for block A, with lower CVs than between 2017 and 2019. Encounter rate estimates were lowest in block E, with higher-than-average CVs. The expected school sizes were lowest in block A, in particular during 2017 – 2019, with estimates of less than 250 individuals per school. Blocks C and E generally had high school sizes. For block C, all but the 2018 estimate were larger than 1000 individuals. For block E, estimates declined from a high in 2017 to a low in 2022. For block A, the estimated number of individuals were highest in 2018 and declined steadily to 2022. For block C, the estimated number of individuals declined between 2017 and 2021, however, came to an overall high in 2022. For block E, the estimated number of individuals declined steadily between 2017 and 2022. Overall, estimated numbers of individuals were highest in block C in 2022. Block C also showed the largest increase in abundance in comparison to previous years. Abundance estimates in blocks A and E are comparable to the last surveys conducted in these blocks. CVs for the individual blocks were overall high – lowest for block A with 31% but generally over 40% otherwise and up to 83% in block E in 2022. The current results are comparable with the previous estimates. As for the biomass estimates, the estimates for the previous years based on the newest detection function are comparable with the estimates from the previous reports. There is an increase in biomass in block A in 2022 despite the same estimates of abundance in 2021. The biomass in block E is comparable to the estimates from 2019 when the last survey took place in that block. The biomass estimates are presented in **Table** and **Figure 1.**

Regarding the model-based analysis, the 514 transect lines were divided into 8146 segments, most of which were approximately 10 km long. Then, different environmental drivers of BFT abundance (bathymetry, chlorophyll, sea-surface temperature, mixed-layer depth, salinity etc.) were tested for each model and the most significant ones were identified. Overall, these models represent a first attempt to produce a global spawning habitat model for Western and Central the Mediterranean based on aerial survey observations. Diagnostics were not ideal and uncertainties were high, suggesting that a lot of variation remains to be explained, and hence further efforts should be dedicated to the refinement of these models. One option that have been considered is that maybe the different surveyed blocks should be considered separately, given that due to the differences in the environmental scenarios among areas the main drivers of BFT spawners distribution could vary among them. This assumption should be more formally tested in the future.

4.2.2 GBYP Aerial survey activities in Phase 13

Despite the promising preliminary results from the pilot survey using digital systems, due to logistic constraints and available budget, the GBYP Steering Committee (SC) decided to resume the aerial survey following the classic human observers-based system. As in 2022, it was decided that the Levantine Sea sub-area (Area G) would not be surveyed given that the results obtained in previous campaigns suggested that one of the basic assumptions to apply this methodology, that is that the BFT spawners are fully available for aerial observations, was not accomplished. Therefore, the three areas which were surveyed were the following: Balearic Sea (Area A), Southern Tyrrhenian Sea (Area C) and Central-southern Mediterranean Sea (Area E).

To keep the time series of this aerial index, which is one of the indices used for the evaluation of the eastern BFT stock within the framework of the new management system based on the MSE approach, the surveys strategy and sighting methodologies were the same as in last campaigns. Therefore, the survey was conducted in the period from the end of May to the beginning of July, following the standard protocol and using classical visual observations.

Before the mission, on 31st May 2023 an on-line training course was held, with the participations of all members of the crews (pilot, professional spotters, 2 scientific spotters), in order to provide them with the detailed instructions on the methodology and the way to fill the sighting forms.

The survey in Area A (Balearic Sea) was carried out with a Cessna 337 plane, from 1-26 June 2023. During this period, there were carried out 18 flights, but on two of these days the sighting work was cancelled because of bad visibility. Because of bad weather conditions or flight bans due to military activities the team stayed on land 8 days. This year the temporal closures of part of the surveyed area due to military exercises obliged the team to adapt the original sampling strategy, covering in some occasions different parts of a given transect of the same replica on different days. Nevertheless, all the 30 initially planned transects, divided into 4 replicas, were flown over. In total, during the time on effort, 36 observations of bluefin were recorded, which summed to more than 27,000 individuals with a total weight of 4,200 t. Most of the observed schools were made up of large individuals (weighting between 150 and 280 kg). The preliminary map (**Figure 2**) shows that the majority of observations were located in the North and North-West of the Ibiza and Majorca islands, as well as in the South-East of Majorca.

The survey in the Southern-Tyrrhenian Sea (area C) was carried out by a plane Partenavia/Vulcanair P68 B model during the period from 2 to 19 June. There were a total of 13 survey flights. During 5 days, the survey had to be cancelled due to weather conditions or unforeseen events. A total of 5 bluefin sightings were realized, of large schools formed by 500-7000 individuals, which summed up to 11,300 individuals with a total weight of more than 690 t. Although the importance of this area for bluefin spawning could be confirmed once again this year, there were less sightings than in previous years. According to the professional spotters' opinions, part of the BFT schools could be deeper and less visible, probably due to high surface sea temperatures. The distribution of sightings is shown in **Figure 3**.

The survey in Area E: Central-Southern Mediterranean Sea (Sicily Channel) was carried out from 20 June to 5 July. Unfortunately, it was impossible to cover the Easternmost part of the study area (around 1/3 of the total), specifically the transects that should be covered from Malta airport, because this year, contrastingly to previous ones and also the criteria followed by Italian and Spanish authorities in the other areas, the Maltese aerial authorities considered that the scientific observers were merely passengers, and hence the contracted aerial company should present different type of certificate. It must be highlighted that the documentation presented by the contracted company was exactly the same than in previous years, in which the authorizations were given without any problem. Therefore, the presentation of a formal protest to Maltese authorities could be considered. As a result of these administrative problems, the four foreseen replicas could only be done in the Western/central part of the study area, having as base port Pantelleria airport. The survey was carried out by two planes, both of them of model Partenavia/Vulcanair P68 B, through 13 survey flights along a 9-day period. In total, 11 bluefin tuna schools were recorded, which represents a similar number as in previous years. However, there was a bigger percentage of medium and large fish compared to 2022. In total, there were 10,650 individuals observed with a total weight of 1,270 t. The distribution of sightings is shown in **Figure 4**.

4.2.3 Workshop on larval indices

The Workshop on ABFT larval indices took place in Palermo from 7-9 February 2023. It was organized by GBYP in a hybrid format. The specific objectives were identifying potential sources of uncertainty or inaccuracy in tuna larval surveys; agreeing on a standard survey methodology to minimize potential sources of error or bias and exploring the possibilities for expanding surveys aiming at producing larval indices to other Bluefin Tuna spawning areas. The survey strategies and sampling methodologies, as well those applied to the analyses of biological samples and data, were exposed by all the research teams currently involved in studies on Atlantic bluefin tuna larval stages and discussed by the Group. Finally, a series of specific points aiming at standardizing methodologies and exploring the possibilities for implementing new BFT larval index surveys, were addressed by the Group, producing a list of action points toward the achievement of this objective.

The workshop was attended by more than 40 scientists from 5 CPCs. The detailed report will be presented to BFT Species Group in September as the document SCRS/2023/042.

4.3 Tagging

This line of research has faced two important problems from the beginning of the program, which have prevented or limited the full achievement of these initial objectives. One was the very low recovery rate of conventional tags, which impedes the use of these data to estimate reliable mortality rates. Because of that GBYP SC decided to cancel the conventional tagging program in Phase 4, initiated in Phase 2 besides the tag awareness and recovery programme, maintaining only complementary conventional tagging activities by providing tags and tagging equipment to different institutions or organizations which ask for this support, as well as maintaining the awareness and rewards activities and the data base integrating all the results from recovered tags. The second major problem along the first phases of GBYP etagging programme has been the relatively short time on fish of most of the

electronic pop-up tags, which limits the usefulness of the recorded data to achieve the stated objectives. The premature releases are attributable to different factors, as technological problems of the tags, fishing activities, death of the fish after tagging and, in general, probably the use of equipment and tagging methodologies not fully adequate for BFT. These potential problems have been addressed through different ways, as the use a new reinforced model of MiniPAT satellite tag designed to minimize "pin broke" problems, selection of tagging areas with lower fishing pressure and exploring and applying whenever possible improved tagging methodologies. In Phase 9 further methodological improvements were introduced in GBYP tagging operations, as the use of a new type of reinforced tether with titanium darts and the use of a retention loop with a second anchor. In addition, an ad hoc workshop on satellite tags deployment methodologies was held for instructing the taggers, including practical sessions. Consequently, the time on fish of the tags deployed in the last years has improved a lot, with an increasingly higher proportion of tags remaining on fish the whole programmed year, for the first time in GBYP tagging campaigns.

4.3.1 Tagging campaigns in 2022

As recommended by the Steering Committee, the tagging activities carried out under contract on specific agreements in the Phase 12 were limited again to the deployment of electronic tags, keeping the deployment of conventional tags only as a complementary activity. As in the previous season, the specific objectives of the 2022 campaign were 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, with the immediate objective to improve the knowledge of the bluefin spatial patterns.

Like in 2021, the GBYP tagging program in 2022 was carried out along with electronic tagging programs developed at national level. This allowed to strengthen the collaboration between GBYP and , taking advantage of the synergies between the different tagging programs and increase the efficiency of each, with the final goal of providing better scientific advice. With this aim, a call for expressions of interest was published in April 2022 (ICCAT Circular #G-0433-2022), for deployment of a total of 54 pop-up satellite tags by experienced tagging teams in the Mediterranean and/or North Atlantic Ocean, targeting eastern stock individuals.

As a response to the call, several expressions of interest were received, describing their work-plan for the deployment of the tags. These were carefully evaluated by the GBYP Steering Committee and the Secretariat staff in order to select the most adequate ones to fulfil SCRS research needs. Consequently, memorandums of understanding were signed between ICCAT and the awarded research teams, to formalize the cooperation. GBYP provided electronic tags and covered the costs of PSATs satellite transmission, while national teams provided the human resources, including experienced scientific personnel in deployment of electronic tags in bluefin tuna and infrastructure required to successfully conduct such tagging operations. It was agreed that the GBYP tags data would be shared by both parties, and that the national teams would provide in the near future the results from their own tags to ICCAT. The following national teams were awarded:

- Technical University of Denmark (DTU) - 6 PSAT tags for their deployment in North Eastern Atlantic water (Eastern North Sea, Skagerrak, Kattegat and Øresund)
- Institute of Marine Research (IMR) of Norway - 5 PSAT tags for their deployment in Norwegian waters
- University of Maine - 10 PSAT tags for their deployment on ABFT <185 cm CFL along the east coast of the US (western Atlantic)
- The Marine Institute - 5 PSAT tags for their deployment in the coastal waters off Ireland
- Swedish University of Agricultural Sciences (SLU) - 6 PSAT tags for their deployment in Skagerrak, Kattegat or the Sound Straight
- Stanford University in collaboration with DFO (Fisheries and Ocean Canada) and Acadia University - 18 PSAT tags (including 9 Lotek tags and 9 WC) for their deployment in Canadian waters
- Government of Jersey in collaboration with Thunnus UK (a collaboration between the Centre for Environment, Fisheries and Aquaculture Science and the University of Exeter) - 5 PSAT tags for their deployment in Channel Island waters (waters of Jersey and Guernsey)

Technical University of Denmark (DTU) deployed, within the framework of the Swedish and Danish collaboration "Scandinavian Bluefin Marathon", a variety of electronic and conventional tags on 174 ABFT (CFL ranging between 210 to 284 cm) in Skagerrak, Kattegat and Øresund over the course of 16 tagging days between 20 August and 2 October 2022. All tagged ABFT were tagged with a conventional tag (ICCAT tag series), and most (170 ABFT) were also tagged with an acoustic tag (Thelma Biotel). Thirty ABFT were also tagged with PSATs, of which 6 were provided by ICCAT GBYP program (under an ad hoc Memorandum of understanding), five were tagged with accelerometer tags and an additional eight were tagged with DST's (Lotek Wireless). Biological

sampling was undertaken during tagging: a fin clip was taken for genetic analysis and a muscle biopsy, blood sample and scales were collected to explore the physiological status (and other parameters) of each tagged individual.

The Institute of Marine Research in Norway deployed the tags along the coast of Norway between the 31st of August and 29th of September 2022. Like in previous years, the major aims were to collect genetic samples of BFT and tag these with both pop-up satellite archival tags (PSATs) and conventional tags as far north as possible. Tagging was performed on-board a specially designed tagging vessel with an aluminium ramp to pull the fish on board. In total, eleven BFT ranging from 237 cm to 283 cm (CFL) in length were tagged with PSATs and conventional tags, and genetic samples were collected. Eight BFT were caught from the tagging vessel, and three individuals were transferred from collaborating recreational fishing boats to the tagging vessel. All fish were caught using rod-and-line and spreader bars as lures.

The Marine Institute carried the electronic tags deployment activities in Donegal Bay (North-West Ireland) on the 8th of August 2022 with all 5 individuals tagged and released with GBYP owned Wildlife Computers, pop-off satellite archival tags (PSAT) and numbered spaghetti tags. The Marine Institute tagged a further 13 Atlantic bluefin tuna in the period from 9th of August to 11th of October in Donegal Bay (N.W. Ireland) and Courtmacsherry Bay (S.W. Ireland) with Wildlife Computers PSATs. All 13 individuals were also tagged with ICCAT issued spaghetti floy tags.

Swedish University of Agricultural Sciences (SLU) deployed a variety of electronic and conventional tags on 48 large (> 219 cm curved fork length) Atlantic bluefin tuna captured by volunteer rod-reel anglers in Skagerrak between August 22 and September 2, 2022. In total, they deployed 18 pop-up satellite archival tags, 6 of which were provided by ICCAT. Additionally, sampling fin clippings was done for each tagged individual for genetic analysis and muscle biopsy to explore the physiological status.

The Government of Jersey, in collaboration with Cefas and Exeter University, as part of the Thunnus UK, deployed two types of electronic tags on 12 ABT (136 to 243 cm curved fork length, CFL; mean ± 1 S.D. = 198 ± 26 cm) off southwest England (n=5) and the Channel Islands (n=7) during September and November 2022. These tags were funded by ICCAT (5 tags), Jersey Government and EU INTERREG. Biological sampling was undertaken at the time of tagging in the form of a fin clip for genetic analysis and a muscle biopsy.

Stanford University, in collaboration with DFO, deployed 16 pop-up tags in the Gulf of St. Lawrence in September and October 2022. 9 of these tags were Wildlife Computers MiniPATs and the rest 7 were Lotek PSAT FLEX tags. In addition, 2 Lotek pop-up tags were deployed in North Carolina in December 2022 and March 2023. Finally, one WC tag was deployed off Canary Islands (Gomera) in April 2023.

The University of Maine was not able to deploy the tags in 2022 as initially planned, due to some logistical problems. It was agreed to attempt to deploy them beginning 2023, but then the tags should be returned to the manufacturer to make a software upgrading to solve the battery issue, which delayed the deployment plans.

Currently available electronic tag tracks from the tags deployed by GBYP are shown on **Figure 5.** In addition to these tags, GBYP also acquired numerous e-tags datasets from other tagging programs through its data recovery activity. Namely, these include tags deployed by Stanford University (Hopkins Marine Station, Block Lab), Large Pelagics Research Center and WWF. The complete tracks currently available in the GBYP repository are shown on **Figure 6**. The electronic tags datasets are being used in MSE for determination of BFT stocks mixing rates.

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.

As regards conventional tags, within Phase 12 “spaghetti” tags, along with applicators and the tagging protocols and forms to report tagging operations were delivered to various institutions (**Table 3**). In addition, conventional tags and related equipment was also delivered to the teams in charge of satellite tags deployment, since in this phase they have been asked to carry out a double tagging whenever possible, implanting conventional tags besides the satellite tags.

In Phase 12, a total of 1555 tags were deployed on 1464 bluefin tuna individuals (**Tables 4** and **5**). The level of tagging was much lower than in the beginning of the Programme, since the conventional tagging was cancelled by the Steering Committee in Phase 4, keeping it only as a complementary activity centred in providing equipment

to conventional tagging operations developed at national level. In total, from the beginning of the Programme up to 1 March 2023, more than 25 thousand bluefin tuna individuals have been tagged, using more than 33 thousand tags of different types (**Tables 6** and **7**).

4.3.2 Tagging campaigns in 2023

In Phase 13, a new Call of Expressions of Interest to collaborate with GBYP e-tagging program was launched in July 2023. As a result, 11 MOUs have been or will be signed, for deployment of 75 additional GBYP owned tags, as follows:

- Acadia institute, in collaboration with DFO (Fisheries and Ocean Canada) and Stanford University - 8 PSAT tags to be deployed in Canadian waters
- Fundación AZTI - 6 PSAT tags to be deployed in the Bay of Biscay
- Technical University of Denmark - 8 PSAT tags to be deployed in North Eastern Atlantic water (Eastern North Sea, Skagerrak, Kattegat and Øresund)
- University of Exeter, in collaboration with Cefas and the Government of Jersey - 4 PSAT tags to be deployed in Jersey territorial waters
- University of Exeter - 4 PSAT tags to be deployed in southwest England
- Institute of Marine Research - 8 PSAT tags to be deployed in Norwegian waters
- The Marine Institute - 8 PSAT tags to be deployed in the coastal waters off Ireland
- Swedish University of Agricultural Sciences -8 PSAT tags to be deployed in Skagerrak, Kattegat and Öresund
- Stanford University, in collaboration with Barcelona ZOO and AZTI - 8 PSAT tags to be deployed off Canary Islands
- Stanford University - 8 PSAT tags to be deployed in the waters off North Carolina
- University of Genova - 5 PSAT tags to be deployed in the Ligurian Sea

4.3.3 Tag recoveries

a) Tag awareness and reward policy

This activity is considered essential for improving the low tag reporting rate existing so far in the Eastern Atlantic and the Mediterranean Sea. The tag awareness material was produced in 12 languages, considering the major languages in the ICCAT convention area and those of the most important fleets fishing in the area: Arabic, Croatian, English, French, Greek, Italian, Japanese, Mandarin, Portuguese, Russian, Spanish and Turkish. Several thousands of posters of various sizes (A1, A3 and A4) and stickers were produced so far and distributed to all major stakeholders, such as Government Agencies, scientific institutions, tuna scientists, tuna industries, fishers, sport fishery federations and associations in the area. In addition, in 2016 two short propaganda videos on ICCAT GBYP tagging activities were produced, which are available in 8 languages through YouTube.

The ICCAT GBYP tag reward policy has been considerably improved since the beginning of the program, with the purpose of increasing the tag recovery rate. The current strategy includes the following rewards: 50€/ or a T-shirt for each spaghetti tag; 1000 € for each electronic tag; annual ICCAT GBYP lottery (September): 1000 € for the first tag drawn and 500 € each for the 2nd and 3rd tag drawn. According to the recovery data, this policy (along with the strong tag awareness activity) was very useful for improving the tag reporting rate.

For further improving the results, meetings with ICCAT ROPs have been organized periodically, further informing them about the ICCAT GBYP tag recovery activity and asking them to pay the maximum attention to tags when observing harvesting in cages or any fishing activity at sea, which have resulted in an increase of recoveries by ICCAT observers in farms.

b) Tag recovery and reporting

The important tag reporting improvement registered after the beginning of the tagging and tag awareness activities by ICCAT GBYP is impressive. So, the average ICCAT recoveries for the period before 2010 were much lower than during GBYP, as shown on **Figure 7**. The first significant increase in the rate of the tag recoveries was recorded from 2012. Such a success should probably be attributed not only to the recent tagging activities, but to the settled tag awareness campaign as well. In the year 2022, a total of 153 tags were recovered. It should be stressed that, in the last couple of years, for the first time in ICCAT bluefin tuna tagging activities, the number of tags recovered and reported from the Mediterranean Sea has been higher than any other area. Considering that reported tags from the Mediterranean were almost nil before GBYP, this is the clear evidence that GBYP tag awareness campaign is producing positive effects.

As for the study of conventional tags shedding rate, 554 tags were recovered from 368 double tagged fish (up to 1 March 2023). According to the results (**Table 8.**), it seems that the double barb tags are more resilient than the single barb tags.

4.3.4 Electronic tagging workshop

The Workshop on ABFT electronic tagging took place in Madrid from 4-6 July 2023. It was organized by GBYP in a hybrid format. The goal of the workshop was to reach a broad consensus on the strategic planning of future electronic tagging and the best use of available tagging data. The specific objectives of the workshop included:

- Identification of remaining knowledge gaps in movement transitions, life history traits and population structure
- Drafting of a strategic plan to fill these gaps
- Discussion of the development of a new ICCAT database (ETAGS DB), that will integrate information from e-tagging activities
- Discussions regarding the access and use of the data contained in the ETAGS DB in light of the recently adopted Rules and Procedures for the protection, access to, and dissemination of data compiled by ICCAT
- Elaboration of a workplan for conducting joint analyses of the combined tagging datasets

The workshop was attended by more than 60 scientists from 12 CPCs. During the workshop, multiple subjects were discussed and a list of priorities for future tagging campaigns were identified. The detailed report will be presented to BFT Species Group in September as the document SCRS/2023/133.

4.4 Biological Studies

One of the core activities of ICCAT GBYP are the so-called Biological Studies, which ICCAT GBYP started in 2011, maintaining a biological sampling programme covering the main bluefin fisheries and funding 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 attention to the age structure and the probable sub-populations identification. Bluefin tuna biological samples are stored in the GBYP Tissue Bank, which is maintained by AZTI.

A general objective of this Phase was to consolidate the new knowledge generated in the different lines of research developed throughout the last decade, carrying out necessary global reanalyses of available data and synthetising the results generated in previous phases, in order to provide sound conclusions that can be directly applied to improve stock management. The particular objectives of biological studies were the following:

- Maintain a GBYP tissue bank capable of providing the samples required to carry out the studies necessary for improving the understanding of key biological and ecological processes affecting BFT, particularly stock piling samples that can be used for population-level genomics studies.
- Update the estimation of key biological parameters and population age structure required for BFT stocks evaluation and management.
- Achieve a better understanding of the BFT population genetic structure.
- Provide accurate and reliable estimates of spatial-temporal and genetic mixing rates between Atlantic BFT populations (western and eastern stocks in the different statistical areas throughout along the year cycle.
- Develop and/or refine methodologies based on microchemical analyses allowing to determine the timing of relevant biological traits throughout the whole life cycle, such as migrations to spawning areas.
- Provide relevant knowledge for the application of the Close-Kin approach to BFT Eastern stock.
- Further study the implementation of an Information System allowing for the proper management of the samples and data generated by the biological studies, integrating not only metadata on sampling and analytical tasks, but whenever possible, the results from such analyses.

In addition to regular biological sampling, in order to guarantee the availability of a sufficient number of samples of adult bluefin tuna, in Phase 12, a dedicated sampling was performed in farms, for fish captured in the Balearic Sea, in the Southern Tyrrhenian Sea and in the South-Central Mediterranean Sea.

4.4.1 Biological sampling and analyses in Phase 12

As done in previous GBYP phases, a call for tenders was issued for maintenance and management of ICCAT GBYP Tissue Bank, collecting tissue samples and otoliths and performing analyses – both microchemistry analyses of otoliths and genetic analyses of tissue samples. Only one offer was received, from AZTI, as leader of a Consortium which included 8 more institutions, which was awarded to. In addition, a call for tenders was published for sampling of adult bluefin tuna individuals in farms. Four offers were received for this concept, out of which two were awarded a contract. Taxon Estudios Ambientales SL was contracted for sampling 300 individuals fished in the Balearic Sea and AquaBioTech was contracted for sampling 300 individuals from the South Tyrrhenian Sea and other 300 from the Central/Southern Mediterranean Sea.

Overall, most of the objectives of the project were met. These analyses continue to provide relevant information for a better understanding of the biology of Atlantic bluefin tuna, which in turn improves the stock assessment and management advice of this valuable species. The main specific activities carried out in relation to biological sampling and analysis of biological samples and their more relevant results are summarized below:

a) Biological sampling

During Phase 12, following sampling protocols agreed in earlier Phases, the Consortium sampled a total of 490 Atlantic bluefin tuna (224 YOY, 3 medium sized fish and 263 large fish) from different regions (52 from the Strait of Gibraltar, 42 from Portugal, 35 from the Canary Islands, 79 from Norway, 100 from the Central North Atlantic, 19 from the South of Spain and 103 from the Balearic Sea and 60 from the Levantine Sea). In total, 980 biological samples (310 otolith samples, 181 fin spines and 489 genetic samples) were collected by the Consortium and incorporated into the tissue bank. The Consortium also received samples apart from those agreed in the contract. In total, the Consortium handled 4555 biological samples (1514 otolith samples, 1221 fin spines and 1820 genetic samples) from 1867 individuals. All these samples have been catalogued and stored together with the biological tissue bank. In addition, 7638 BFT larvae from IEO-CSIC BFT 2022 larval survey (co-funded by EU DCF), were identified, sorted and fixed following protocols to allow its future use in genetic analyses. The information from this and previous phases is being reviewed and uploaded to a new application developed in AZTI, considering suggestions from GBYP dada management specialist. The total number of bluefin tuna individuals and samples collected in the Phase 12 is shown in **Table 9**.

b) Biological analyses

Genetic analyses

On genetic analyses, interbreeding dynamics in the Slope Sea confirmed a gene-flow from the Mediterranean into the Slope Sea, which is probably a relatively recent, from the evolutionary point of view, event (less than approximately 80 generations). The individual ancestry composition assuming two ancestral populations is shown on **Figure 8.** The genetic mixing of Mediterranean and western origin individuals in the Slope Sea could have happened repeatedly in different years during the last decades. An increase in gene flow from 2008 to 2018 could not be confirmed, although this hypothesis could not be rejected. Also, genomic regions of albacore origin were found in the genome of Slope Sea and Mediterranean individuals for which whole genome sequencing data was available. The data suggested that variants of albacore origin are associated to adaptive traits. The identification of these regions will allow searching for specific genes and derived functions to understand how these affects adaptive capability of the Atlantic bluefin tuna to the environment.

In this phase complete assignments of Atlantic bluefin tuna individuals from feeding aggregates along the North Atlantic captured at the different ICCAT areas, genotyped with the 96 SNP traceability panel from GBYP phase 6 to phase 11, have been updated based on the knowledge on the population structure acquired during the GBYP program. Overall, > 3,200 individuals captured at feeding aggregates showed varying mixing proportions of Mediterranean, Gulf of Mexico, and unassigned individuals across catch years, supporting the hypothesis that migratory patterns of Atlantic bluefin tuna are dynamic. Proportion of samples assigned to Mediterranean or Gulf of Mexico from the different ICCAT areas are shown on **Figure 9** (overall proportions) and **Figure 10** (proportions per catch year).

The Consortium also presented a cost-effective tool for kin pair identification for future CKMR studies. Thus, a custom SNP array designed to genotype more than 8,000 SNPs in Atlantic bluefin tuna samples for population structure, CKMR and genomic adaptation analyses was proved as a valid tool for kin pair detection among eastern samples. In total four half and one full sibling pairs were identified among 359 sample set, which mainly included

larvae from the Balearic Island captured in 2020. It was concluded that minimally 2,000 SNPs markers, among those included in the custom SNP array, were required for effective kin finding among eastern individuals. It was also found that the sex markers included in the 96 SNP traceability panel and the custom SNP array allow to correctly identify sex at a 94% correct rate.

Direct ageing

Regarding direct ageing, three subtasks have been completed. A review and update of bluefin tuna growth studies using calcified structures and methods combined with these structures has been carried out. It resulted in detailing the status of validation and standardization of the reading of each structure Next, two reference collections of 200 samples have been prepared for otoliths and for spines (first spiny ray of the first caudal fin) to serve as quality control of these structures. Finally, a selection of otolith samples has been made to carry out the epigenetic study for the ABFT of the East Atlantic and Mediterranean Sea. This selection has considered all possible factors that may influence the analyses.

Otolith chemistry

Regarding otolith microchemistry, new carbon (δ13C) and oxygen (δ18O) stable isotope analyses were carried out on the Atlantic bluefin tuna samples captured in the foraging grounds of the Atlantic Ocean. Results suggest that individuals originated both in the GOM and MED cross the 45°W management boundary, mixing with the other population in feeding aggregates of the Atlantic Ocean, this rate being different among years. The proportion of fish from GOM origin found to cross to the east is smaller than the proportion of MED origin fish found that cross to the west. There may be two explanations for this finding: (1) fish originating in the GOM tend to move less, and (2) being a smaller stock in terms of production, the chances of finding a fish from the GOM are lower, or be a combination of both. As shown on **Figure 11**, there is an increasing linear trend in the presence of MED origin relative to GOM origin fish in the North Atlantic. In other areas (West and South Atlantic), observed year to year variations in origin composition did not follow a linear trend.

Individual origin has also been evaluated geographically to get an overview of the last decade. The results showed a spatial separation of catches within the North Atlantic Ocean: fisheries operating in the eastern North Atlantic dominated by the Mediterranean origin fish, western Atlantic coast dominated by the Gulf of Mexico origin fish, and central North Atlantic catches composed by a mixture of stocks. As shown on **Figure 12**, these results provide strong evidence of longitudinal population structuring of bluefin tuna in the North Atlantic Ocean and demonstrate the capacity of otolith chemistry to determine their natal origin, at both spatial and interannual time-scales. Therefore, for an effective stock management, it is important to monitor temporal variations in mixing ratios, especially in the current scenario of changing environment.

Integrated analysis

During this phase, further efforts have been made to combine genetic and chemical markers to develop a combined method of population assignment. Over the previous Phases of the GBYP programme ABFT individuals had been routinely analyzed to assign stock of origin based on otolith chemistry and genetic markers separately to investigate the degree of eastern and western population contribution to different mixing areas in the Atlantic Ocean. However, the use of both methods together can provide further insights into the complexity of the stock structure of the species and enhance the understanding of ecological and evolutionary processes that may help to identify stock units with a high degree of confidence. Here, two different approaches were followed: (1) Individual origin was re-assigned using an integrated classification model that includes both genetic and stable isotope data (i.e., Integrated approach) and (2) genetic and stable isotope data was used complementarily (i.e., Combined approach). The integrated method proved to increase the resolving power of stock discrimination in comparison to single approaches and resulted in lower numbers of unassigned individuals than otolith stable isotope only and genetic markers only models. The combined approach showed that can provide insights into ABFT population structure that can be masked when a single technique is used, or when both techniques are integrated, as it considers processes occurring at different temporal scales (i.e., individual life span vs evolutionary), as shown on **Figure 13.**

Larvae sorting, identification and counting

Finally, ABFT larvae from surveys conducted in the Balearic Sea spawning ground were sorted and identified for potential close-kin analyses. In total, 7638 individuals from 40 samples collected during 2022 were identified. Bluefin tuna larvae were found in 34 out of the 40 samples analyzed. In addition, stages of larval development were identified (i.e., yolk sac, preflexion, flexion, or postflexion). The sorted individuals were preserved in 100% ethanol in different 4 ml jars and kept in the freezer for a perfect conservation.

4.4.2 Epigenetic Ageing pilot study

Although the Close-Kin Mark-Recapture method has already been implemented on Western ABFT, the ICCAT SCRS is still evaluating the financial, logistic and scientific feasibility of implementing it on Eastern stock. One of the main issues that could prevent the implementation of CKMR is the high cost of age determination by means of classic schlerochronological methods. A potential solution would be the DNA methylation-based epigenetic ageing method, which has shown promising results in other commercial fish species. Yet, obtained age estimates may have quite high error margins compared to otolith derived ages.

Therefore, GBYP in Phase 12 has carried out a pilot study to evaluate the potential of using the epigenetics for ageing Atlantic Bluefin Tuna individuals, with the aim to evaluate both the accuracy and the feasibility of the epigenetic method compared to direct ageing by otoliths readings. The need for implementing this task was identified rather late, after the initial plan for Phase 12 was drafted so it implied reallocating funds dedicated to other activities and extending the duration of Phase 12.

Three offers were received as a response to the Call for Tenders issued in January 2023 for this purpose. The contract was awarded to Commonwealth Scientific and Industrial Research Organisation (CSIRO). The particular aims of the study were to:

- calibrate an epigenetic age model using the approach developed by Mayne *et al.,* 2021 and tissue samples from eastern and western stocks with age data from standardized ICCAT otolith reading methods,
- examine the influence of stock and sex on epigenetic age calibration,
- assess the relative cost-effectiveness with the use of otolith-based age estimation for use in CKMR for eastern BFT.

Although several sub-tasks of this study have been completed (sample characteristics, provenance determination, sex determination and epigenetic age calibration and prediction), the overall study has unfortunately not been terminated by the end of Phase 12, due to substantial delays in the installation and programming of a new genetic sequencing robot replacement in the CSIRO lab, replacing the one that had been planned to be used initially, which suffered a breakdown. The pending sub-tasks are the sequencing, bioinformatics and calibration of the epigenetic age model. It is envisaged that all these pending tasks will be completed by September 2023 and to present the results to the September 2023 BFT Species Group meeting.

4.4.3 Workshop on Close-Kin Mark Recapture, including biological sampling coordination

The Workshop on CKMR and biological sampling coordination took place in Madrid from 14-16 March 2023. It was organized by GBYP in a hybrid format. It focused on the analysis of relevant factors for the implementation of the approach in the eastern Atlantic bluefin tuna stock, with the goal of presenting a feasibility study, including a workplan with cost estimations, to the SCRS in 2024. The requirements for CKMR and the current knowledge of Atlantic bluefin tuna (ABFT) reproduction and population structure were reviewed, and examples of applications of CKMR methodologies in other fish species were provided. The genetic studies carried out to date for ABFT stock identification, kinship analyses, sex determination and epigenetic ageing, were summarized and discussed. It was proposed that a comparison be made between the two methodological approaches applied thus far for kinship determination in ABFT, i.e., the one applied in the ongoing Western stock CKMR study and the one developed under the GBYP program, and that the possibility of including alternative techniques be explored. Sampling opportunities for ABFT Eastern stock CKMR implementation were discussed. Finally, a list of recommendations for future steps and a tentative timeline for their implementation was elaborated.

The workshop was attended by more than 50 scientists from 8 CPCs. The detailed report will be presented to BFT Species Group in September as the document SCRS/2023/043.

In order to obtain the advice on CKMR approach and assistance in preparation of the Workshop, Dr Mark Bravington was contracted. Dr. Mark Bravington has been a leading CSIRO expert on CKMR, who already participated in providing the initial advice on CKMR approach to ICCAT in previous years. His tasks were the following:

- provide advice regarding the planning of the Workshop and preparation of the reference document compiling the consolidated knowledge on BFT relevant for CKMR implementation

– active participation in the Workshop, including a general presentation of CKMR process (purpose and design), preferably also referring to the gene tagging method, and assistance with preparing the report from the Workshop.

4.5 Modelling

The modelling programme addresses the GBYP general objective 3, which is to "Improve assessment models and provision of scientific advice on stock status through improved modelling of key biological processes, 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".

Initially, it was planned that GBYP start carrying out operational modelling studies only from the year 4 of the program, but following the recommendation of Steering Committee and SCRS, the modelling activities already started from the year 2. It became evident that this line of study has greater importance than perceived in the moment when GBYP was conceived, and hence the amount of effort for this activity has been much larger than initially considered. In addition, the MSE process being embarked upon by ICCAT has been an important initiative which represents a significant investment of time and resources by the Commission, CPCs and scientists involved.

An initial ICCAT GBYP multi-annual modelling work plan for the MSE was proposed at the Core Modelling Group meeting held in Monterrey in 2016, based on the Gloucester meeting. The main objective of MSE is to provide advice that is robust to uncertainty, and this requires a number of steps, namely:

- Identification of management objectives and mapping these into statistical indicators of performance;
- Selection of hypotheses for considering in the Operating Models (OMs) that represent the simulated versions of reality;
- Conditioning of the OMs based on data and knowledge, and weighting of model hypotheses depending on their plausibility;
- Identifying candidate management strategies and coding these as Management Procedures;
- Projecting the OM forward in time using the MPs as a feedback control in order to simulate the long-term impact of management (Ramaprasad, 1983); and
- Identifying the Management Procedure that best robustly meets management objectives.

To successfully conduct an MSE requires the engagement of stakeholders to evaluate alternative management actions and the risks of not meeting management objectives. Conducting an MSE allows the consequences of the improvement of knowledge, collection of data and implementation of alternative management measures to be evaluated.

Under previous contracts an OM (a mathematical simulation model), capable of a number of variations, has been coded and is available in the software repository https://github.com/ICCAT/abft-mse. In addition, a manual has been provided which forms the basis of a Software Development Plan (SDP) for future development. This will allow multiple developers to collaborate in its development and the development of candidate MPs in the future.

The development of the OM required test units to be developed to ensure that the code is fit for use, and in particular to ensure that resource dynamics in the OM are implemented as agreed by the Bluefin WG and the Technical MSE Group (formerly Core Modelling Group (CMG)). This required that the individual source code procedures and modules together with associated control data, usage procedures, and operating procedures, be tested. This will also help to avoid errors when the code is revised, and when collaboration involves multiple developers.

4.5.1 MSE development in Phase 12 by GBYP contracted expert

In Phase 12 the contract for modelling approaches for providing support to bluefin tuna stock assessment was again awarded to Dr Tom Carruthers (Blue Matter Science, Canada), who initiated the work on MSE modelling in 2014. The contract was envisaged to cover the activities until the end of 2022. Nevertheless, in February 2023 the MSE Technical Group defined further MSE tasks necessary for meeting the SCRS planned schedule. Therefore, another contract was provided to the modelling expert to cover the period until July 2023.

The contracts in Phase 12 covered the final stages of MSE development in support of MP adoption, including final tuning of CMPs, rescaling of latest index data, drafting of exceptional circumstances protocols and additional presentation materials in support of MP selection. In addition, they included the development of an exceptional circumstances app that can help design effective protocols given the various data types available to Atlantic bluefin

tuna. Also, the computer code was commented and supporting documentation developed, that guide a technical user on how to reproduce and rebuild the ABTMSE R package from scratch.

The principal developments in Phase 12 were the following:

- Finalization of shiny apps
- Finalization of TSD
- Rescaling analyses allowing for update indices
- A variety of presentation and communications materials in support of MP adoption.
- Documentation for building the ABTMSE R package and ECP app
- Open-source ECP R package that contains all code, functions and diagnostics.
- A new ECP Shiny app for exploring and developing ECP for bluefin tuna
- Draft SCRS on ECP background and proposals for bluefin tuna
- Adopted MP code check.

Summing up, all MSE processes upstream of MP adoption are complete. Identification of exceptional circumstances protocols is outstanding and provides a link back to operating model specification if triggered (**Figure 14**).

4.5.2 BFT MSE Technical Group

In order to support the important and complex MSE development by an effective coordinating body with the required technical expertise and appreciation of needs of the SCRS and Commission, in 2014 the GBYP Core Modelling and MSE Group was created. The Steering Committee provided its terms of reference and recommended the membership of the Group. The Group was intended to provide technical oversight and advice on the MSE process and review technical contributions and outputs of the work program. From December 2014 to 2017 the Group held 6 meetings. During the MSE intersessional meeting on 16-20 April 2018, it was decided to formalize the creation of the BFT MSE Technical Group, which, unlike Core Modelling Group, would be open to all interested ICCAT scientists, without restriction to participation. Therefore, GBYP Core Modelling Group was dissolved and it was substituted by the BFT MSE Technical Group. Nevertheless, although this Group was not formally constituted within the framework of Programme GBYP, it has continued providing its support, by covering the travel expenses, whenever needed, for participating in MSE related meetings of the members of the previous MSE Core Modelling Group.

In Phase 12 GBYP supported the travel of the MSE Coordinator (Dr Doug Butterworth) and the MSE modelling expert (Dr Tom Carruthers) to MSE/BFT Species Groups/SCRS meetings in September 2022.

Table 1. GBYP Budget by type of activity, per Phase.

	Phase 1	*Phase 2*	*Phase 3*	*Phase 4*	*Phase5*	*Phase 6*
Coordination	210,000	453,000	225,000	600,245	342,000	383,000
Data Recovery	200,000	149,000	30,000	40,250	20,000	165,000
Aerial Survey	300,000	465,000		518,426	519,500	
Biological Studies		505,000	430,000	364,000	363,000	556,000
Tagging	40,000	890,000	1,175,000	1,229,979	669,500	844,000
Modelling		40,000	65,000	122,100	211,000	177,000
FINAL	750,000	2,502,000	1,925,000	2,875,000	2,125,000	2,125,000

	Phase 7	*Phase 8*	*Phase 9*	*Phase 10*	*Phase 11*	*Phase 12*
Coordination	415,745	312,500	227,000	478,000	379.000	491.000
Data Recovery	25,000	58,000			55.000	30.000
Aerial Survey	405,000	494,500	535,775	321,000	370.000	80.000
Biological Studies	580,000	583,000	710,000	750,000	380.000	494.500
Tagging	262,000	159,000	177,500	315,000	221.000	262.500
Modelling	121,240	143,000	99,725	136,000	195.000	142.000
FINAL	1,808,985	1,750,000	1,750,000	2,000,000	1.600.000	1.500.000

Table 2. Estimated biomass (B, in tons) per block along with its coefficient of variation (CV), lower and upper 95% confidence limits (LCL and UCL). The same columns with 'str' apply to estimates reported in previous years.

	B	*CV*	*LCL*	*UCL*	*B_str*	*CV_str*	*LCL_str*	*UCL_str*
A-2017	8969	0.43	3894	20660	8001	0.45	3436	18634
A-2018	14931	0.3	8265	26975	13345	0.31	7352	24222
A-2019	13332	0.39	6227	28546	11548	0.38	5619	23734
A-2021	8156	0.54	2947	22575	4714	0.53	1750	12696
A-2022	11704	0.44	5025	27263	-	-	-	-
C-2017	7733	0.38	3638	16436	6749	0.43	2981	15280
C-2018	5849	0.55	2030	16857	5069	0.54	1846	13920
C-2019	3567	0.56	1204	10571	3072	0.62	977	9652
C-2022	6909	0.41	3078	15512	-	-	-	-
E-2017	5669	0.58	1908	16849	5884	0.6	1981	17483
E-2018	4443	0.54	1608	12278	3735	0.47	1538	9067
E-2019	3074	0.46	1273	7427	2023	0.5	797	5188
E-2022	602	0.79	146	2494	-	-	-	-

Table 3. Number of conventional tags sent to different collaborators in Phase 12 (from March 2022 until March 2023).

Country	*Institution*	*Conventional tags (number)*
United Kingdom	Centre for Environment Fisheries and Aquaculture Science	2200
United Kingdom	Swansea University	150
United Kingdom	Agri-Food and Biosciences Institute	300
EU-Spain	CISC-BALEARES IMEDEA	25

Table 4. Number of fish tagged during Phase 12 (from March 2022 until March 2023).

	ALL FISH TAGGED	*FISH SINGLE TAGGED*			*FISH DOUBLE TAGGED*		
		FT-1-94	*FIM-96 or BFIM-96*	*Mini-PATs*	*Double Tags - Conventional*	*Mini-PATS + Conv.*	*Mini-PATS + 2Conv.*
Canada	16	0	0	0	0	16	0
West Med.	78	73	0	5	0	0	0
North and Celtic Seas	1347	49	1242	3	29	18	6
Canary Islands	10	0	0	0	0	10	0
Northwest Atlantic	13	5	0	8	0	0	0
GRAND TOTAL	1464	127	1242	16	29	44	6
		SUBTOTAL = 1385			SUBTOTAL = 79		

Table 5. Number of tags implanted during Phase 12 (from March 2022 until March 2023).

	TOTAL NUMBER OF TAGS	*TAGS IMPLANTED*		
		FT-1-94	*FIM-96 or BFIM-96*	*Mini-PATs*
Canada	32	16	0	16
West Med.	78	73	0	5
North and Celtic Seas	1412	101	1284	27
Canary Islands	20	10	0	10
Northwest Atlantic	13	5	0	8
TOTAL	1555	205	1284	66

Table 6. Number of fish tagged since the beginning of GBYP (up to 1 March 2023).

	ALL FISH TAGGED	FISH SINGLE TAGGED			FISH DOUBLE TAGGED						
		FT-1-94	FIM-96 or BFIM-96	Mini-PATs	Double Tags -	Mini-PATS + Conv.	Mini-PATS + 2Conv.	MiniPAT+ Acoustic+	Archivals + Conv.	Archivals + 2Conv.	Acoustic + Conv.
Canada	2178	0	2139	0	0	23	0	0	0	0	0
Bay of Biscay (a)	7718	4179	15	3	3493	18	0	0	16	0	0
Morocco	365	129	48	45	121	14	0	7	0	0	1
Portugal	347	53	39	94	154	7	0	0	0	0	0
Strait of Gibraltar	5561	2254	43	0	3212	22	5	0	23	2	0
West Med.	1921	1154	377	33	352	5	0	0	0	0	0
Central Med.	3509	1264	1707	32	479	15	0	0	12	0	0
East Med.	122	59	0	50	0	13	0	0	0	0	0
North and Celtic Seas	3792	524	2986	16	130	89	42	0	5	0	0
Canary Islands	11	0	0	0	0	10	0	0	1	0	0
Northwest Atlantic	18	5	0	8	0	3	0	0	2	0	0
GRAND TOTAL	**25542**	**9621**	**7354**	**281**	**7941**	**219**	**47**	**7**	**59**	**2**	**1**
		SUBTOTAL = 17256			**SUBTOTAL = 8276**						

Table 7. Number of tags implanted since the beginning of GBYP (up to 1 March 2023).

	TOTAL NUMBER OF TAGS	*TAGS IMPLANTED*				
		FT-1-94	*FIM-96 or BFIM-96*	*Mini-PATs*	*Archivals*	*Acoustic*
Canada	2217	29	2149	39	0	0
Bay of Biscay	11245	7700	3508	21	16	0
Morocco	515	258	183	66	0	8
Portugal	508	182	225	101	0	0
Strait of Gibraltar	8618	5491	3075	27	25	0
West Med.	2277	1507	732	38	0	0
Central Med.	3915	1743	2113	47	12	0
East Med.	135	72	0	63	0	0
North and Celtic Seas	4107	747	3208	147	5	0
Canary Islands	22	11	0	10	1	0
Northwest Atlantic	23	10	0	11	2	0
TOTAL	33582	17750	15193	570	61	8

Table 8. Tag recoveries from double tagged fish by type (up to 1 March 2023).

Release	*Spaghetti tag only*	*Double Barb Tag only*	*Both*	*TOTAL FISH*	*TOTAL TAGS*
2011	8	9	13	30	43
2012	20	35	57	112	169
2013	36	46	86	168	254
2016	1	2	1	4	5
2017	7	14	15	36	51
2018	0	1	2	3	5
2019	0	0	0	0	0
2020	0	1	3	4	7
2021	0	0	0	0	0
2022	0	2	9	11	20
2023	0	0	0	0	0
Total N	72	110	186	368	554
Total percent	20%	30%	50%		

Table 9. Total number of bluefin tuna sampled in Phase 12 by area and size class.

Grand Area	*Area*	*Age 0 <3kg*	*Juveniles 3-25 kg*	*Medium 25-100 kg*	*Large >100 kg*	*TOTAL*
Strait of Gibraltar	Gibraltar Strait	7			45	52
	Portugal (Algarve)			3	39	42
Western Mediterranean	South Spain	19				19
					2	2
	Balearic Sea	12				12
		91				91
					330	330
				1	10	11
Central Mediterranean	Strait of Sicily/Malta				41	41
					346	346
	Tyrrhenian Sea			12	339	351
					3	3
Eastern Mediterranean	Levantine Sea	80				80
East Atlantic-West African Coast	Canary Islands	35				35
					3	3
Northeast Atlantic	Bay of Biscay		1	17	35	53
			31	48	157	236
North east Atlantic	Norwegian Sea				79	79
Central North Atlantic	Central and North Atlantic				100	100
Gulf Saint Lawrence	Gulf Saint Lawrence				1	1
Total		244	32	81	1530	1887

Figure 1. Estimated biomass (in tons) of BFT for surveyed years and blocks. Orange colour show estimates from this study: dots show mean values and ribbon show upper and lower confidence limits of the 95% confidence interval. Grey colour shows estimates from the previous years for comparison ('strict update').

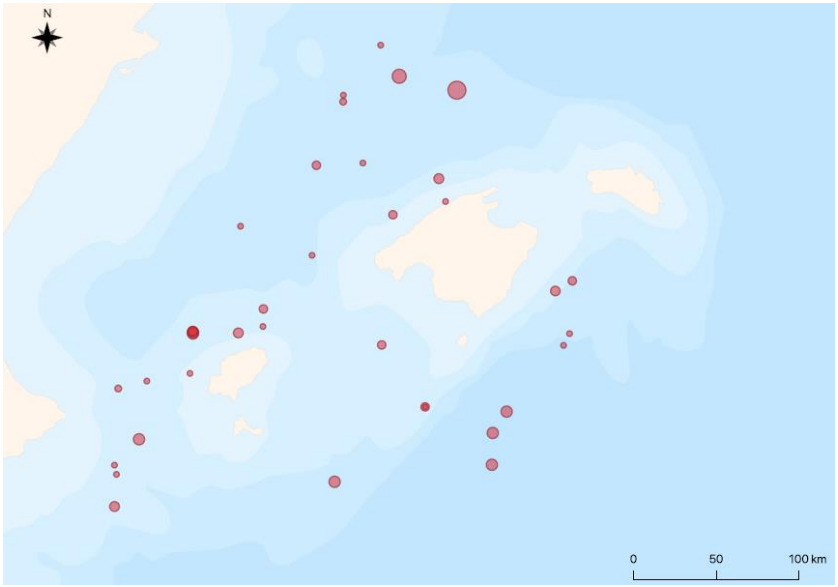

Figure 2. Bluefin tuna observations in the Balearic Sea area.

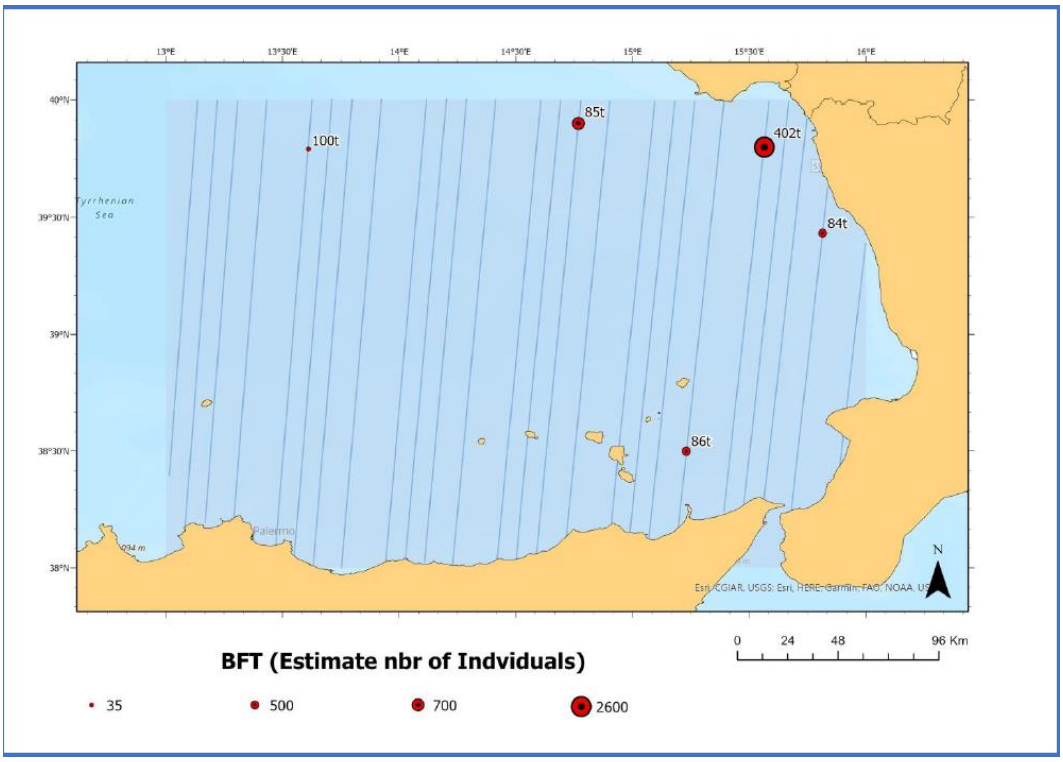

Figure 3. Bluefin tuna observations in the Southern Tyrrhenian Sea area.

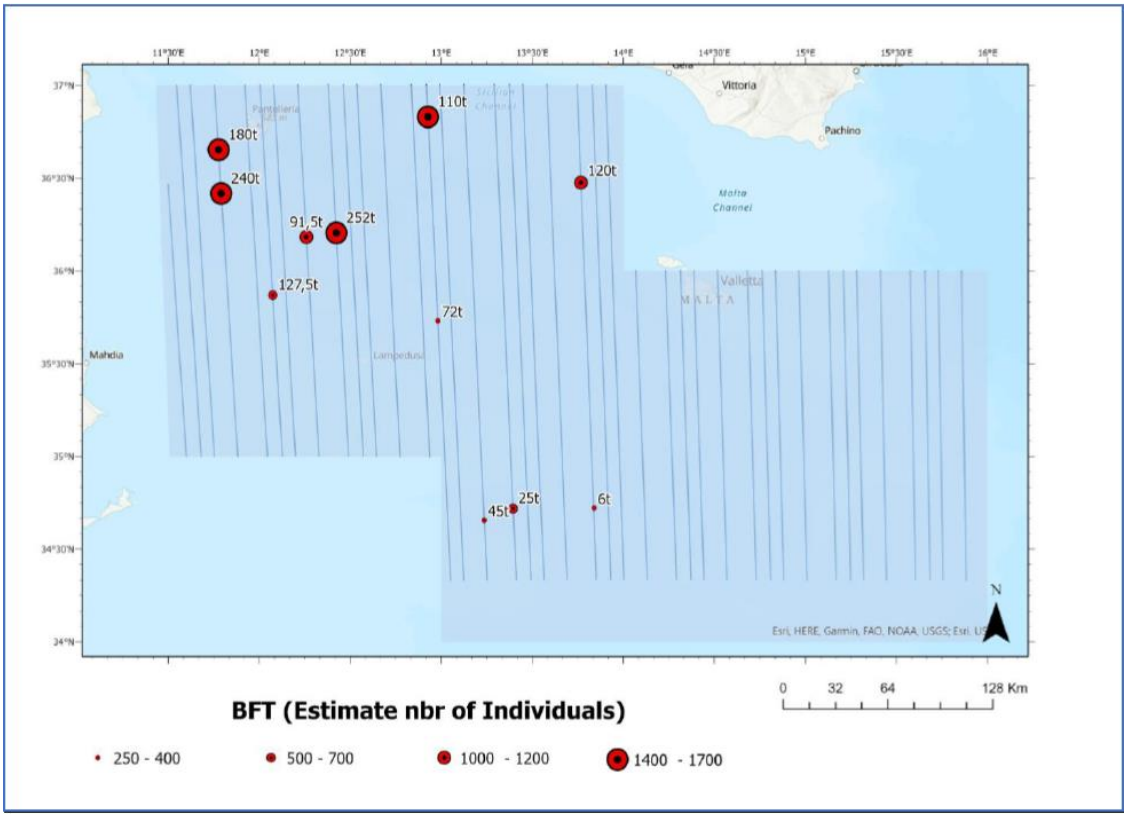

Figure 4. Bluefin tuna observations in the Central-Southern Mediterranean Sea.

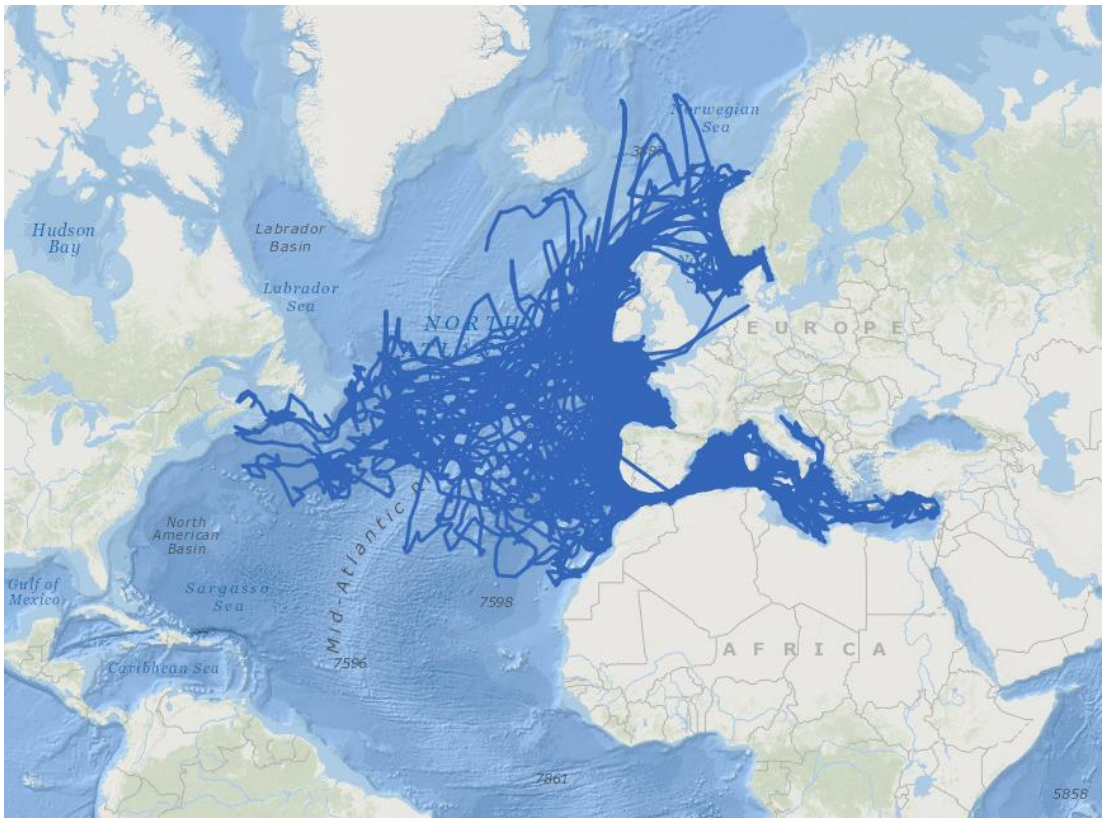

Figure 5. Currently available electronic tag tracks, for tags deployed by GBYP.

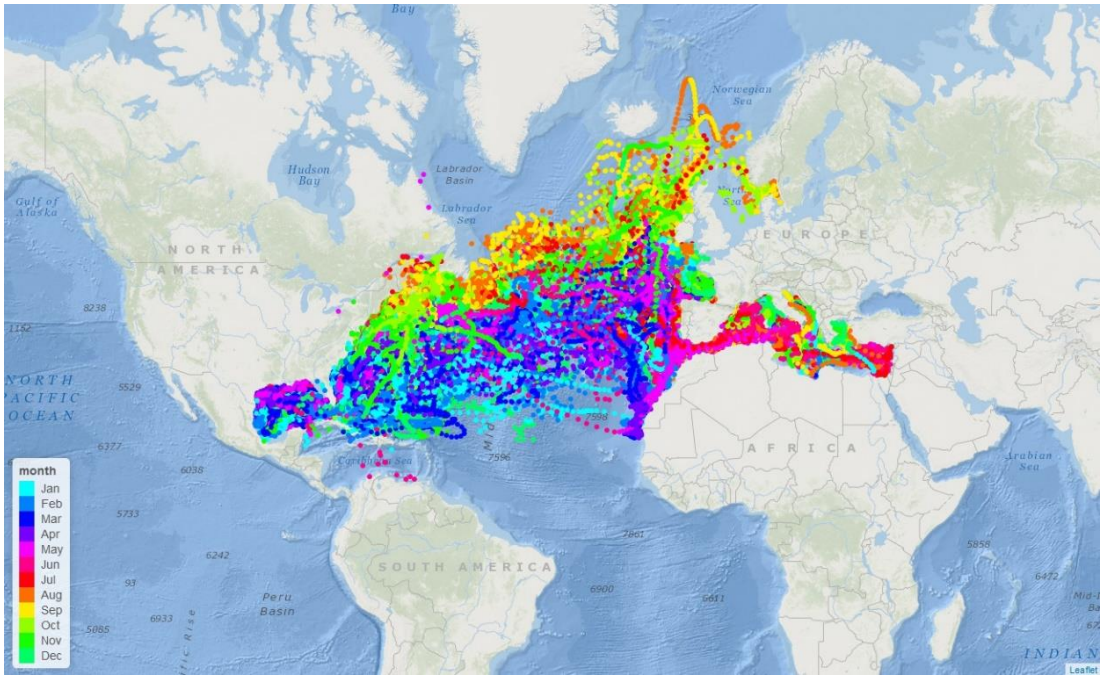

Figure 6. Currently available electronic tags tracks, for tags deployed by GBYP and acquired through data recovery activity from other programs. Daily positions are colored by month.

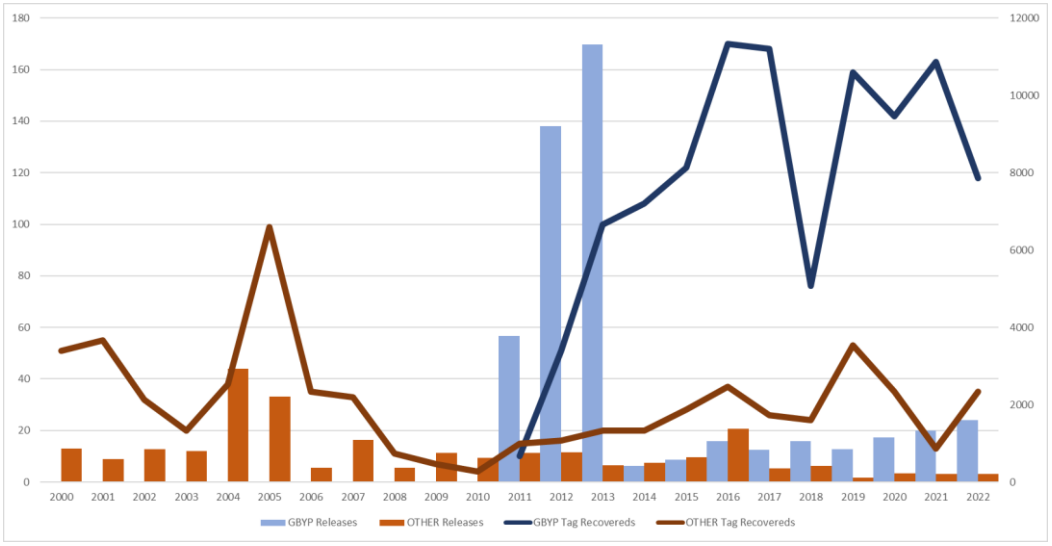

Figure 7. Annual trend of bluefin tuna tag recoveries reported to ICCAT since 2002 (up to 1 March 2023).

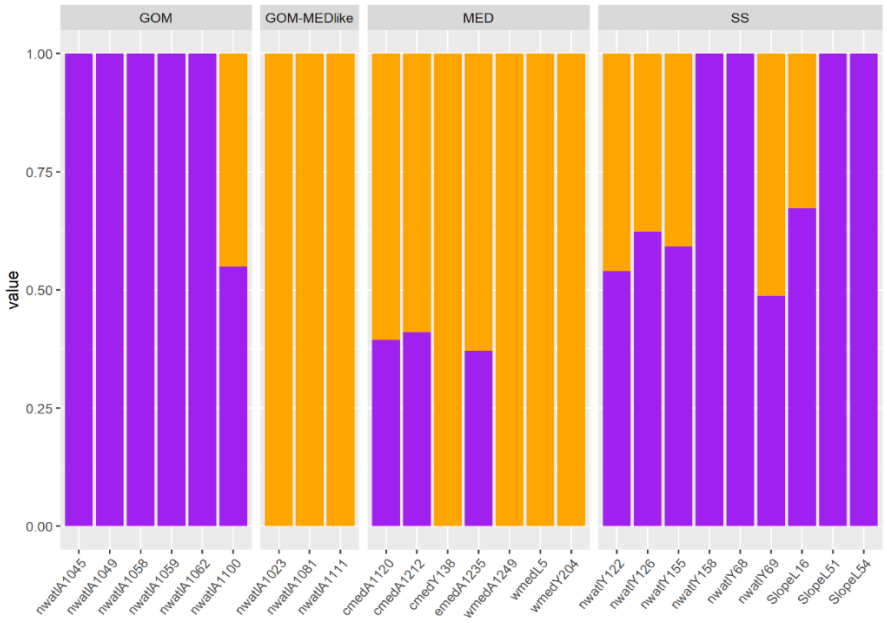

Figure 8. Individual ancestry composition assuming two ancestral populations. The orange and purple components correspond to the Mediterranean and Gulf of Mexico ancestral populations respectively. Individuals are grouped as captured in the Slope Sea (SS), in the Mediterranean Sea (MED), in the Gulf of Mexico (GOM) and those captured in the Gulf of Mexico but known to show Mediterranean origin (GOM-MED like).

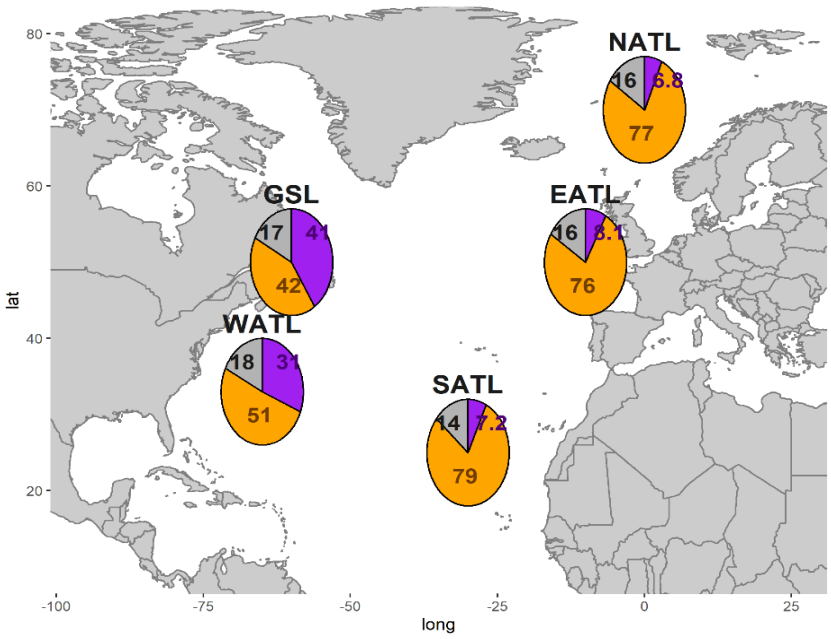

Figure 9. Proportion of samples assigned to Mediterranean (orange) or Gulf of Mexico (purple origin and unassigned (grey) from the different ICCAT areas (GSL= Gulf Saint Lawrence, WATL=West Atlantic, SATL=South Atlantic, EATL=East Atlantic and NATL=North Atlantic).

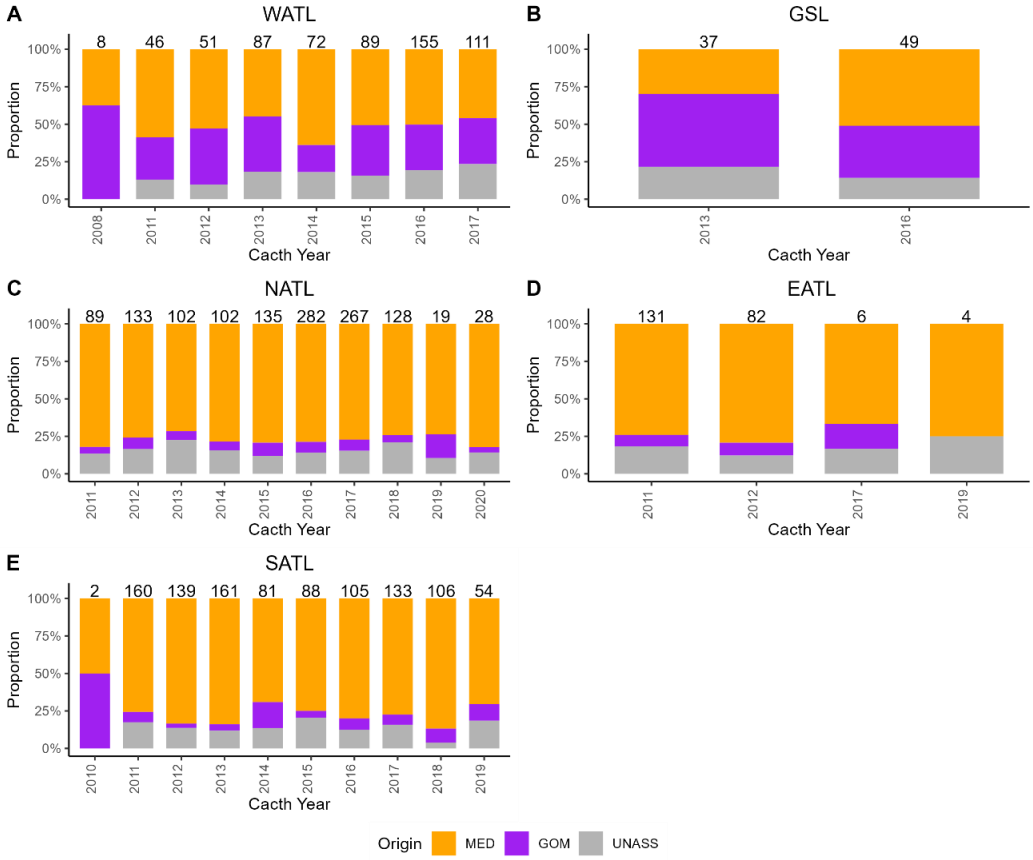

Figure 10. Proportion of samples assigned to Mediterranean (orange) or Gulf of Mexico (purple origin and unassigned (grey) from the different ICCAT areas (GSL= Gulf Saint Lawrence, WATL=West Atlantic, SATL=South Atlantic, EATL=East Atlantic and NATL=North Atlantic) and catch year.

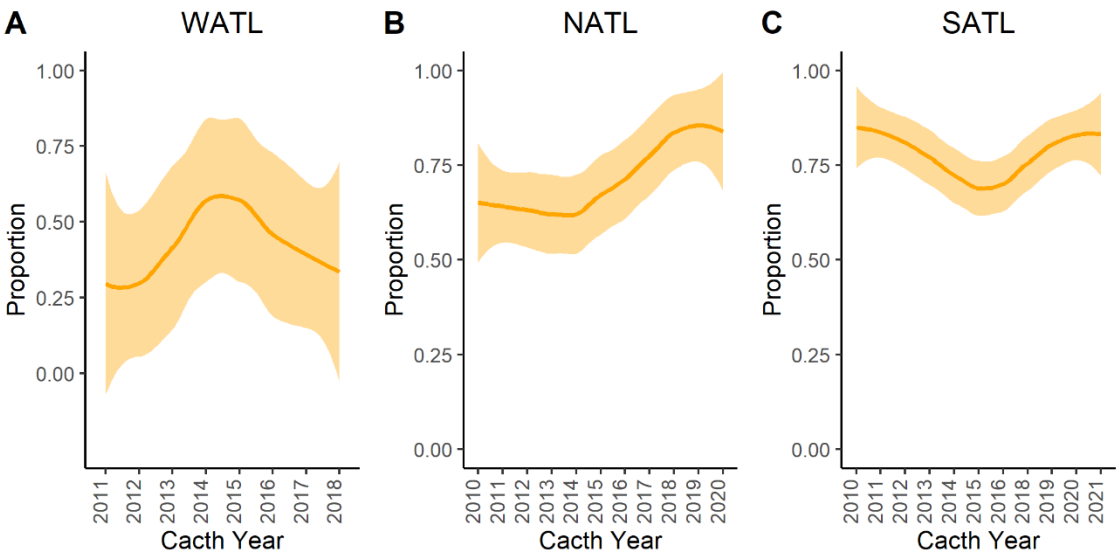

Figure 11. Temporal evolution of estimated proportions of MED origin of Atlantic bluefin tuna samples collected in the West (WATL), North (NATL) and South (SATL) Atlantic Ocean.

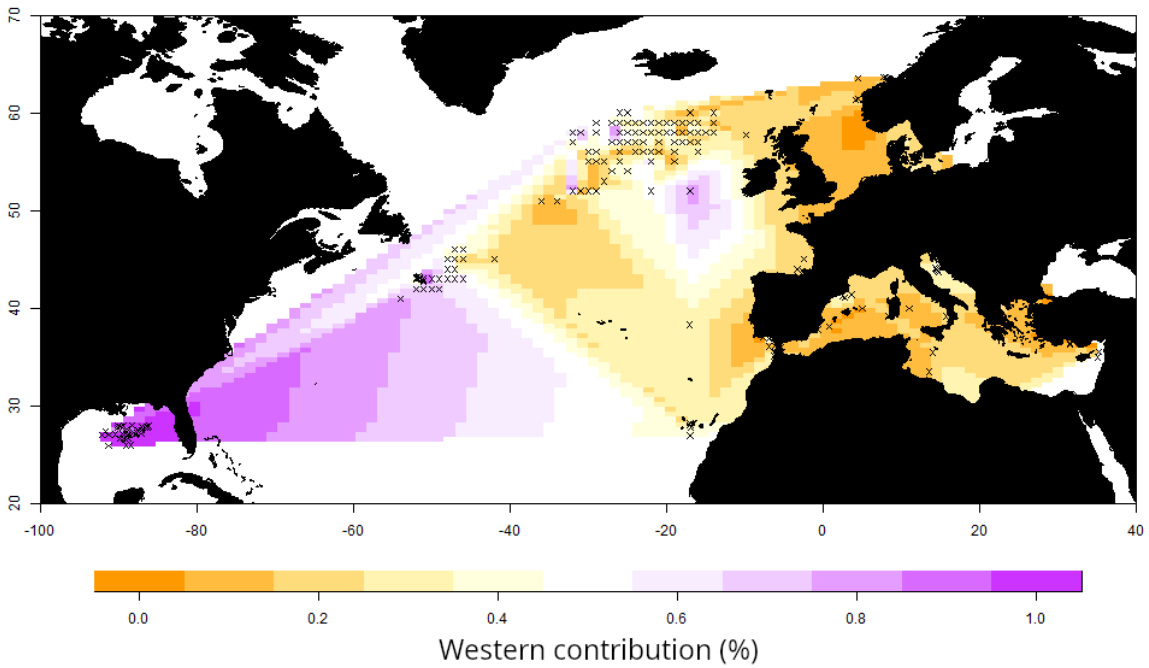

Figure 12. Western contribution estimated by individual origin assignment using Quadratic Discriminant Analysis. Data from 2019 to 2022 were combined and interpolated among the sampled positions (represented by "x"). Mean values were estimated for data from the same catch location.

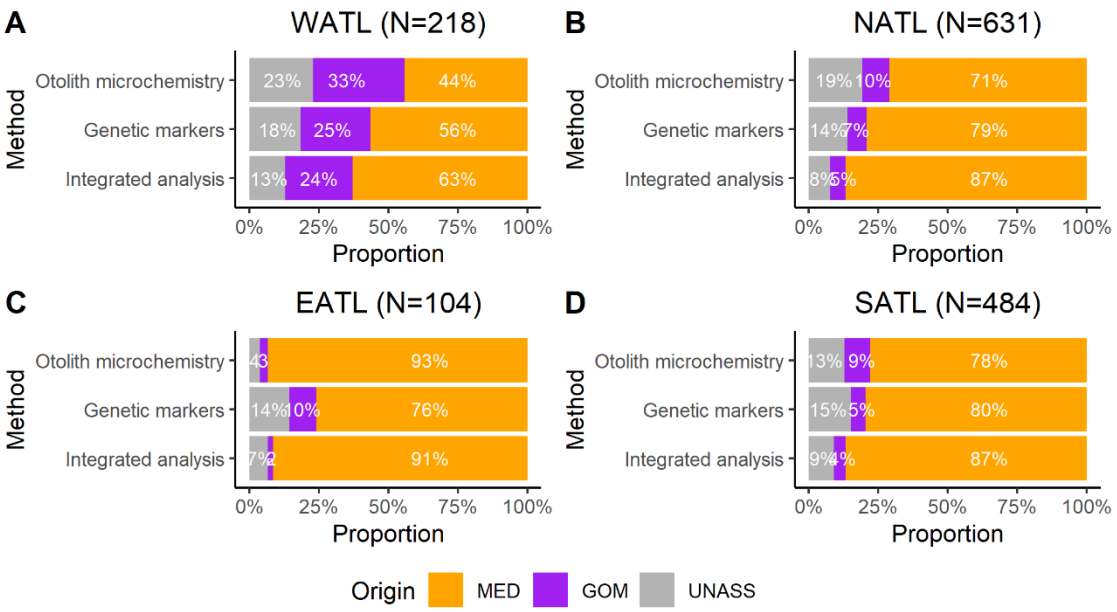

Figure 13. Estimated proportions of MED (orange), GOM (purple) and unassigned (grey) origin of ABFT captured in the West (WATL), North (NATL), East (EATL) and South (SATL) Atlantic Ocean by method; (1) otolith stable isotope data, (2) genetic markers and (3) integrated approach.

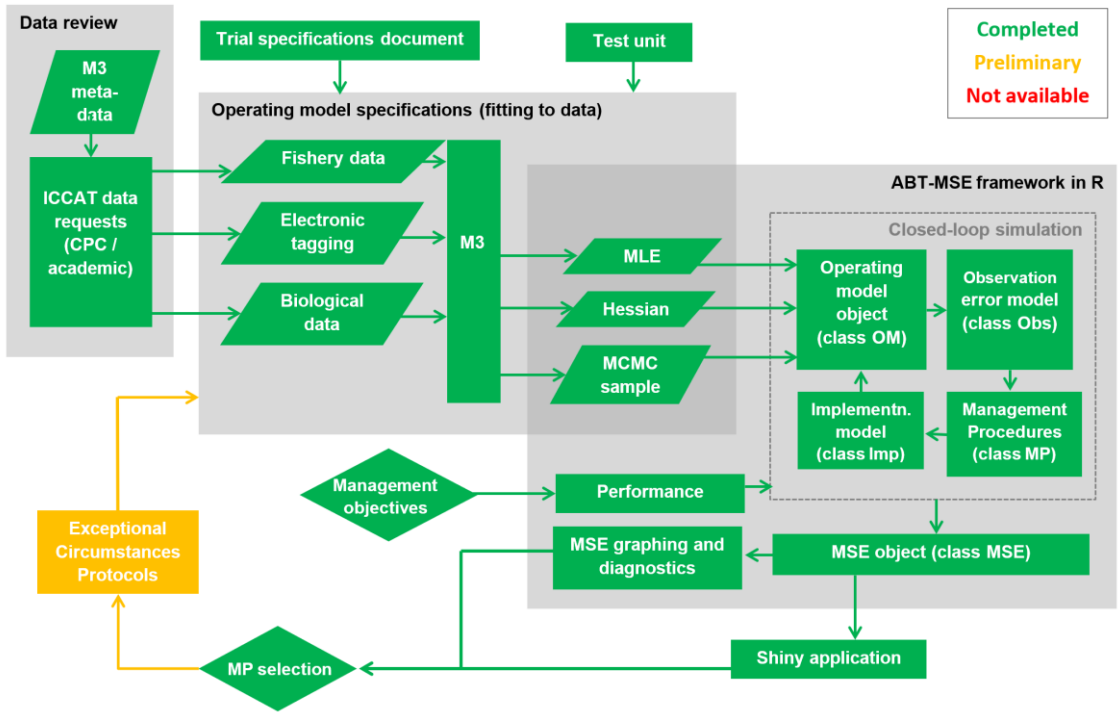

Figure 14. All components of the ABT MSE framework components upstream of MP adoption are now completed.

Annex 1

GBYP Contracts and MOUs issued in Phase 12

COORDINATION				
ACTIVITY	*RETAINED PROPOSAL*	*working schedule*		*COST*
		initial date	*final date*	
10/2022	Steering Committee External Expert – Ana Parma	02/11/2022	24/03/2023	11.250,00 €
DATA MINING AND MANAGEMENT				
ACTIVITY	*RETAINED PROPOSAL*	*working schedule*		*COST*
		initial date	*final date*	
11/2022	Big Fish Intelligence Company Limited- Dr. Tim Lam (Hong Kong)	26/09/2022	20/03/2023	30.000,00 €
AERIAL SURVEY				
ACTIVITY	*RETAINED PROPOSAL*	*working schedule*		*COST*
		initial date	*final date*	
12/2022	AS 2021 Data analysis - University St Andrews – Creem (United Kingdom) and CSIC-IEO (Spain)	24/11/2022	20/03/2022	£39.761 and 20.000,00 €
TAGGING PROGRAMME				
ACTIVITY	*RETAINED PROPOSAL*	*working schedule*		*COST*
		initial date	*final date*	
MoU	Tagging in North Eastern Atlantic waters - DTU Technical University of Denmark	15/07/2022	23/07/2023	-
MoU	Tagging off Norway - IMR Institute of Marine Research (Norway)	19/07/2022	23/07/2023	-
MoU	Tagging in Celtic Sea - MI Marine Institute (Ireland) and Stanford University (USA)	12/08/2022	23/07/2023	-
MoU	Tagging in North Eastern Atlantic waters - SLU Swedish University of Agricultural Sciences	06/07/2022	23/07/2023	-
MoU	Tagging in Canada – Stanford University (USA) and DFO (Canada)	18/10/2022	23/07/2023	-
MoU	Tagging in Mediterranean traps - Balfego (Spain)	06/09/2022	23/07/2023	-
MoU	Tagging off Jersey – Government of Jersey and Thunnus UK (UK)	31/10/2022	23/07/2023	-
MoU	Tagging off East USA cost – University of Maine (USA)	29/08/2022	23/07/2023	-

BIOLOGICAL SAMPLING AND ANALYSES				
ACTIVITY	*RETAINED PROPOSAL*	*working schedule*		*COST*
		initial date	*final date*	
08/2022	Biological studies sampling and analyses – Consortium led by AZTI (Spain)	23/09/2022	02/06/2023	285.532,00 €
09/2022-A	Sampling adult BFT in farms – AquaBioTech (Malta)	27/09/2022	15/03/2023	25.500,00 €
06/2021-A	Sampling adult BFT in farms – Taxon (Spain)	23/09/2022	15/03/2023	45.398,73 €
1/2023	Advice on CKMR Workshop - Mark Bravington (Australia)	01/03/2023	24/03/2023	8.400,00 €
2/2023	Epigenetic ageing pilot study - CSIRO Commonwealth Scientific and Industrial Organization (Australia)	18/05/2023	23/07/2023	US$ 68,841
MODELLING APPROACHES				
ACTIVITY	*RETAINED PROPOSAL*	*working schedule*		*COST*
		initial date	*final date*	
8/2022	MSE Expert – Blue Matter Science (Canada)	23/08/2022	31/12/2022	50.000,00 €
3/2023	MSE Expert – Blue Matter Science (Canada)	24/04/2023	20/07/2023	50.000,00 €