Report of the ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP)
(Activity report for the last part of Phase 13 and the first part of Phase 14 - 2023-2024)

1. Introduction

The ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP) officially started at the end of 2009 with the objectives of improving a) basic data collection, including fishery independent data; b) understanding of key biological and ecological processes; and c) assessment models and provision of scientific advice on stock status. The general information about GBYP activities and results, as well as information on budgetary and other administrative issues of the GBYP programme, from the beginning of the programme until today, are available on the GBYP webpage. All the relevant documents related to programme development, including final reports of every activity and the derived scientific papers, Annual Reports to the Standing Committee Research and Statistics (SCRS) and European Union, GBYP workshops or Steering Committee (SC) meeting reports, are also readily available on the GBYP webpage.

Phase 13 of GBYP officially started on 1 May 2023 following the signing of the Grant Agreement for the co-financing of GBYP Phase 13 (Project 101133291) and ended on 31 July 2024. Phase 14 started on 1 February 2024 (Grant Agreement 101169569), and is scheduled to run for 23 months, as a biannual project covering the GBYP activities throughout 2024 and 2025. Therefore, this report describes the activities carried between September 2023 and December 2024.

2. Scientific activities and results achieved by main line of activity

2.1 Data recovery and management

No data recovery activities have been carried out in Phases 13 and 14, given that no new relevant old data sets have been detected. Thus, in addition to the routine data management tasks, such as the update of the data repository to store the information from the aerial surveys activity, contribution to the updating of the ICCAT conventional tags database (DB) and compilation of relevant data sets to attend six external data requests, most of the efforts have been focused on the development of relational databases. The latter aim at the proper storage and analysis of biological data originated by the research activities and of those related to the electronic tagging program.

Once the development stage is concluded, the biological data relational database will integrate all available relevant information, provided by GBYP or by CPC national research teams. It will also allow to develop broad collaborative studies to estimate more reliable biological parameters and to optimize sampling programs, ensuring that they are complementary.

In relation to electronic tags (ETAGS) DB, the testing conducted with the stored datasets revealed various issues which will have to be addressed in the future phases, along with the further optimization of the database functioning and its fine tuning. Moreover, as an additional component of the ETAGS DB, a new metadata set, including a large number of essential data from the main electronic tags manufacturer and satellite service provider, has been added. It will allow to analyze in detail the performance of the satellite tags used (for all the ICCAT species), and hence addressing the requests from the SCRS in this line. Once all relevant datasets are incorporated and compiled, the ETAGS DB will allow performing broad joint analyses, which will contribute to improving knowledge on BFT population structure and spatial patterns.

2.2 Stock fishery independent indices: GBYP Aerial Survey on bluefin tuna spawning aggregations and BFT larval surveys

Two main types of activities have been undertaken in relation to GBYP Aerial Surveys during this reporting period: the updating of the index time series incorporating the results from 2023 and 2024 campaigns, and the development of new campaigns during the summer 2024.

Regarding the 2024 GBYP aerial surveys, four replicates were covered both in Balearic Sea (Area A) and Central Mediterranean (areas C and E), between the end of May and the beginning of July, following the same design and sighting methodology used in 2023. Before the missions, an on-line training course was held with the participation of all members of the crew (pilot, professional spotters, 2 scientific spotters), to provide them with detailed instructions on the methodology and the way to fill the sighting forms.

The survey in Area A (Balearic Sea) was carried out from 4-24 June 2024. To cover the entire four replicas (30 transects in total), 16 flights were made in 14 days. In total, during the time on effort, 12 observations of bluefin were recorded, which summed to more than 1,935 individuals with a total weight of 403 t. Of these, there were seven observations of small groups ranging from 10 to 30 individuals which ranged from small to medium category of fish. The other five observations corresponded to schools of tuna ranging from 100 to 1,000 individuals, made up mainly of fish of the medium to giant category. The majority of BFT observations were located in the western part of the block and mostly in the southwestern part around Ibiza and between Mallorca and Ibiza.

The survey in the Southern-Tyrrhenian Sea (area C) was carried out from 4 June to 6 July 2024. There was a total of 13 survey flights. Only three bluefin schools were sighted, of medium-large schools, which summed up to 3,000 individuals with a total weight of more than 460 t. Although the importance of this area for bluefin spawning could be confirmed once again this year, there were less sightings than in previous surveys. 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 survey in Area E (Central-Southern Mediterranean Sea) was carried out through 20 survey flights, from 7 June to 1 July 2024. Unfortunately, due to the extension of the area and bad weather conditions, it was not possible to carry out the fourth replica over the entire area. In total, 14 bluefin tuna schools were recorded, which represents a similar number to that recorded in previous years. Six of these were composed of small individuals in feeding activities. So only eight were composed by adult of medium and large size, that can be used for spawning stock biomass (SSB) index. In total, there were 10,690 individuals observed with a total weight of 1,060 t. For further details, see the Reports on 2024 Aerial Surveys (Documents section, Phase 14) (available here).

Two contracts were awarded to the Centre for Research into Ecological and Environmental Modelling (CREEM) team of the University of St. Andrews aiming the aerial surveys data analyses. CREEM are the original developers of the DISTANCE methodology applied for the GBYP aerial surveys data analyses. Such contracts comprised the analysis of the 2023 (Phase 13) and 2024 (Phase 14) aerial survey data, respectively, as well as the updating of the estimates from the previous surveys. In both cases the tuna indices were updated in two ways: 1) update of the whole time series (Task 1); and 2) strict update of the index for 2023 and 2024 (Task 2), respectively. To provide a strict update, as requested by SCRS, the detection function used the first time that GBYP aerial survey data were incorporated to BFT management strategy evaluation (MSE) system was applied. While adding new data and calculating a new detection function based on updated data (Task 1), standard error and confidence intervals for the previous years can be updated and, frequently, reduced. The approach used in Task 2 does not allow for such updates as the calculation is based on detection functions originated from a reduced data set. Therefore, the experts recommended using the Task 1 approach to generate the index time series used within the BFT MSE framework. For the distance sampling analysis, only on-effort sightings and sightings of non-juveniles' schools were considered. Sightings described as 100% small (individuals <25 kg) were, therefore, excluded. However, the remaining sightings may still include some schools that contain small individuals amongst larger fish.

Regarding the 2023 survey, as occurred in previous years, most sightings were recorded in block A (Balearic Sea). The school sizes observed in 2023 were, on average, larger than in the previous years. This was also reflected in the second largest average observed biomass in the time series (the peak was observed in 2021). The update of the tuna indices for 2023 showed an increase in BFT both abundance and biomass in blocks A and E and decrease in block C. In 2024 the highest encounter rates corresponded also to block A. The school sizes were, contrastingly to 2023, smaller than in previous years (period 2021-2023), and similar to those observed in the period 2017-2019. Biomass and abundance values also decreased in relation to 2023 records, in all areas. Further information regarding the reports is available here (Documents section, Phases 13 and 14, respectively).

2.3 Tagging activities

This line of research has faced several problems from the beginning of the program, as low recovery rates, premature release of electronic tags due to inadequate tagging methodologies or technical problems of the tag (e.g. pin-broke, battery issues, etc.). These problems have been minimized along the previous GBYP phases through awareness actions and methodological improvements, which increased significantly the time spent on fish and the percentage of recovered tags during the last years. Unfortunately, an additional technical problem affected the performance of the satellite tags deployed within GBYP program, which has resulted in a higher than usual percentage of the tags showing poor or no data transmissions. Therefore, intensive work has been done, in close collaboration with the tags manufacturing company, to prevent and minimize the negative effects of these potential problems. That included the provision of all tagging teams of strict tags maintenance and testing protocols, as well as tagware improvements carried out by the manufacturer.

2.3.1 Tagging campaigns

As in previous phases, the GBYP tagging program in 2023 and 2024 was carried out along with electronic tagging programs developed at national level, which has allowed to strengthen collaboration with national teams, taking advantage of the synergies between the different tagging programs, increasing its efficiency.

Within Phase 13, 13 Memoranda of Understandings (MoUs) were signed with different institutions that applied to the Call launched in July 2023 to collaborate with GBYP e-tagging program, which allowed the deployment of 70 of the 75 pop-up satellite tags awarded. So, only the campaign planned to be carried out in the Ligurian sea could not be performed due to "force majeure" reasons, but the 5 remaining tags will be deployed within Phase 14 tagging MoUs. For further details, see reports on tagging campaigns available here (Documents section, Phase 13).

Within Phase 14 a new Call for expressions of interest was launched in July 2024, which resulted in 10 new MoUs signed, to deploy a total of 109 GBYP owned electronic tags, including: satellite tags, but also internal archival tags and acoustic transmitters, as summarized in **Table 1**.

Table 1. Number and type of electronic tags awarded by team in Phase 14 – year 2024.

Institution	***Tag type***		
	Pop-up satellite archival tag ***(PSAT)***	***Internal***	***Acoustic***
Marine Institute	4		8
Technical University of Denmark (DTU)	6		8
Acadia University	5		
AZTI	4	8	
Stanford (Canaries)	6		5
Zoo Barcelona	3	4	8
Stanford (Slope Sea)	8	6	
Exeter University	4		3
Institute of Marine Research (IMR)	5		
Swedish University of Agricultural Sciences (SLU)	6		8
TOTAL	**51**	**18**	**40**

As regards conventional tags, within Phase 13, 1,750 "spaghetti" tags, along with applicators and the tagging protocols and forms to report tagging operations, were delivered following *ad hoc* requests from institutions located in Canada, Denmark, Italy, Sweden and United Kingdom. During this reporting period, a total of 630 fish were tagged.

2.3.2 Tag recoveries

The ICCAT GBYP tag recovery activities, supported by awareness and reward programs, have continued as usual throughout the reporting period. The current tag recovery strategy includes the following rewards: €50 or a T-shirt for each conventional tag; €100 for each acoustic tags, €1,000 for each archival electronic tag. In addition, the annual ICCAT GBYP lottery (September 2024) included: €1,000 for the first tag drawn and €500 each for the second and third tag drawn. This rewards policy, along with the strong tag awareness activity, including meetings with ICCAT Regional Observer Program (ROP) representatives, have proved to be very useful for improving the tag recoveries. As a result, an exponential increase of electronic tags recoveries has occurred over the last years, coinciding with the specific awareness actions directed to ICCAT observers, which have raised from number around or well below 10 by year before 2020 to a mean of more than 30 tags from 2021, reaching maximum values of 52 tags both in 2023 and 2024.

2.4 Biological studies

2.4.1. Biological sampling and analyses

A call for tenders was issued in Phase 13 for the maintenance and management of ICCAT GBYP Tissue Bank, the collection of tissue samples and otoliths, and genetic studies aiming at deepening in the knowledge of BFT stocks structure and dynamics. As a result, two contracts were awarded.

The first contract included biological sampling of juvenile and adult fishes, specifically 1,384 samples from 732 tuna from different regions (Balearic Sea, Central Mediterranean, Canary Islands, Norwegian Sea and Central Atlantic), as well as the updating of the catalogue of samples stored in the GBYP Tissue Bank. The catalogue is available through a link to a persistent and reliable AZTI public web repository. This user-friendly interface has been developed within a Shiny app and offers an integrated and interactive data visualization tool enabling compiling data from multiple databases and data sources.

Another activity included sorting and identifying larvae from surveys conducted in the Balearic Sea spawning ground for potential close-kin analyses. In total, 2,923 individuals from 25 samples collected during 2023 were identified. Bluefin tuna larvae were found in 21 out of the 25 samples analyzed. The sorted individuals were preserved in ethanol and kept in the freezer for perfect conservation.

As regards genetic studies, several tasks were addressed, which are summarized below.

A set of candidate gene variants potentially affecting Atlantic bluefin tuna fitness, originated from a past introgression event (transfer of genetic information from one species to another as a result of hybridization) from albacore tuna that occurred in the Mediterranean, were identified based on whole genome sequencing analysis. The detection of these albacore alleles in Slope Sea larvae and young-of-the-year (YOY) validated the connectivity between the Mediterranean and Slope Sea spawning areas.

Genetic variants affecting fitness at earliest life stages of Atlantic bluefin tuna were studied by comparing genetic differentiation between larvae and YoY. The finding of candidate genomic variants affecting survivorship during the earliest life-stages of the Atlantic bluefin tuna means an advance in the understanding of the genomic basis of adaptive capacity of the species to changing environmental conditions, as the progressive increase in sea surface temperatures during BFT spawning period and intense heat waves observed in recent decades in the main BFT spawning areas, which could have a direct impact on species recruitment process and hence on stocks abundance.

The suitability of the larvae for kinship analysis required for Close-Kin Mark-Recapture (CKMR) model implementation in the eastern Atlantic bluefin tuna was confirmed. In addition, the results suggested that adult individuals may spawn at different locations in the western Mediterranean during the same spawning season. To determine spatial and temporal connectivity between spawning sites in the Mediterranean Sea and spawning site fidelity at a fine scale within the Mediterranean Sea, further studies and increased sampling size are required.

The genetic origin of individuals that could have not been determined based on the 96 single nucleotide polymorphism (SNP) panel developed in previous GBYP Phases was explored again using the recently developed BFT SNP array including more than 7,000 SNP, which allowed to assign a specific stock of origin to most of these previously unassigned individuals. It was found that the studies based on the 96 SNP panel could have overestimated the proportion of Gulf of Mexico individuals and the mixing of both components at both sides of the North Atlantic Ocean. This fact highlighted the need for a more comprehensive and powerful tool, such as the new BFT SNP Array, for Atlantic bluefin tuna monitoring, aiming the provision of more accurate information about the genetic origin of Atlantic bluefin tuna, mixing dynamics and behavior.

The genetic profile of bluefin tuna captured in the Bay of Biscay in different seasons showed that individuals of Mediterranean and Gulf of Mexico origin can be found in the Bay of Biscay at different proportions across different years, seasons and age classes, suggesting dynamic migratory behavior of the species. These analyses showed that the unusual increased catches of Atlantic bluefin tuna occurring in the Bay of Biscay during the winter over the last three years were composed by individuals of Mediterranean origin, although higher samples sizes are needed to infer more robust conclusions.

Another activity was evaluating the sex assignment power of genetic markers included in the SNP array, with the objective to set hypothesis of sex-biased migration. The results showed an assignment rate of 92.6%. In conclusion, the correct sex assignation of the Atlantic BFT samples using the genetic markers for sex determination included in the SNP array will allow a reliable automated sex identification of Atlantic BFT individuals, minimizing the costs required for the kinship analysis needed for the implementation of CKMR.

Further information regarding the final report by the Consortium led by AZTI is available here (Document section, Phase 13).

The second contract was awarded to investigate the adaptive divergence in Atlantic bluefin tuna using Whole Genome Sequencing (WGS), with the objective of better characterizing the population structure and mechanisms driving evolutionary divergence. The results, based on samples representing Atlantic bluefin tuna populations in the western and eastern Atlantic, including Mediterranean Sea, showed significant genomic variation between both areas. Detailed results are available here (Document section, Phase 13).

Within Phase 14, a new contract was awarded for the maintenance of the GBYP Tissue Bank and to develop further studies related to CKMR feasibility, aiming at identifying haplotypes whose low frequency would allow to use them to know if two individuals share the same mother (objective 1), and to evaluate the sibship among BFT larvae sampled within the Balearic Sea EU DCF ichthyoplankton survey (objective 2).

To address objective 1, three different datasets based on genomic sequences were prepared: one including pool whole genomic sequencing data, another including individual whole genome sequencing data and, finally, a third dataset was generated from the publicly available GeneBank database. The study concluded that these datasets will enable future analysis of mitochondrial variability in the Atlantic BFT Mediterranean population, which is the first step in determining the feasibility of cost-effective assays targeting suitable mitochondrial genomic regions to determine mitochondrial haplotypes.

To address objective 2, larvae from the Balearic Sea spawning ground were sorted from different stations, including high, medium and low larval density ones, and genotyped. No parent-offspring pairs were found, but full-sibling and half-sibling pairs were identified. The analysis revealed high proportions of sibship within some stations and confirmed that one adult can spawn across multiple stations in a season. Further information is available here (Document section, Phase 14).

2.5 Modelling approaches

Regarding MSE, within GBYP Phase 13, support was provided for further development and implementation of the MSE process by covering the travel expenses to BFT MSE Technical Group members. New MSE modelling related to MSE Operating Model (OM) reconditioning are planned to be addressed again in GBYP Phase 14 throughout 2025. In addition, to investigate different sampling options required for the implementation of CKMR to BFT Eastern stock, checking what kind of precision might be and by when, a contract was awarded to produce an initial model presented and discussed within the 2024 ICCAT Intersessional Meeting of Bluefin Tuna Species Group (BFTSG) (hybrid/ Sliema, Malta, 15-18 April 2024)

(ICCAT, 2024). The main conclusion of this modelling work was that it is possible to set and implement sampling levels at a small number of selected fisheries (and a larval survey), to provide by 2030 a very good precision on adult abundance (~10% CVs) and on Z (in effect on M) – under reasonable working assumptions about spatial structure and current abundance. There should also be enough kin-pairs of particular types to check assumptions about spatial structure, e.g. extent of spawning site fidelity. Further information is available here (Documents section, Papers, Phase 13) and Bravington and Fernandez, 2024.

References

Bravington M., and Fernandez C. 2024. Model-based sampling design for eastern bluefin tuna close-kin mark recapture. Collect. Vol. Sci. Paps ICCAT, 81(5): 1-32.

ICCAT, 2024. Report of the 2024 ICCAT Intersessional Meeting of Bluefin Tuna Species Group (BFTSG) (hybrid/ Sliema, Malta, 15-18 April 2024). Collect. Vol. Sci. Paps ICCAT, 81(5): 1-70.