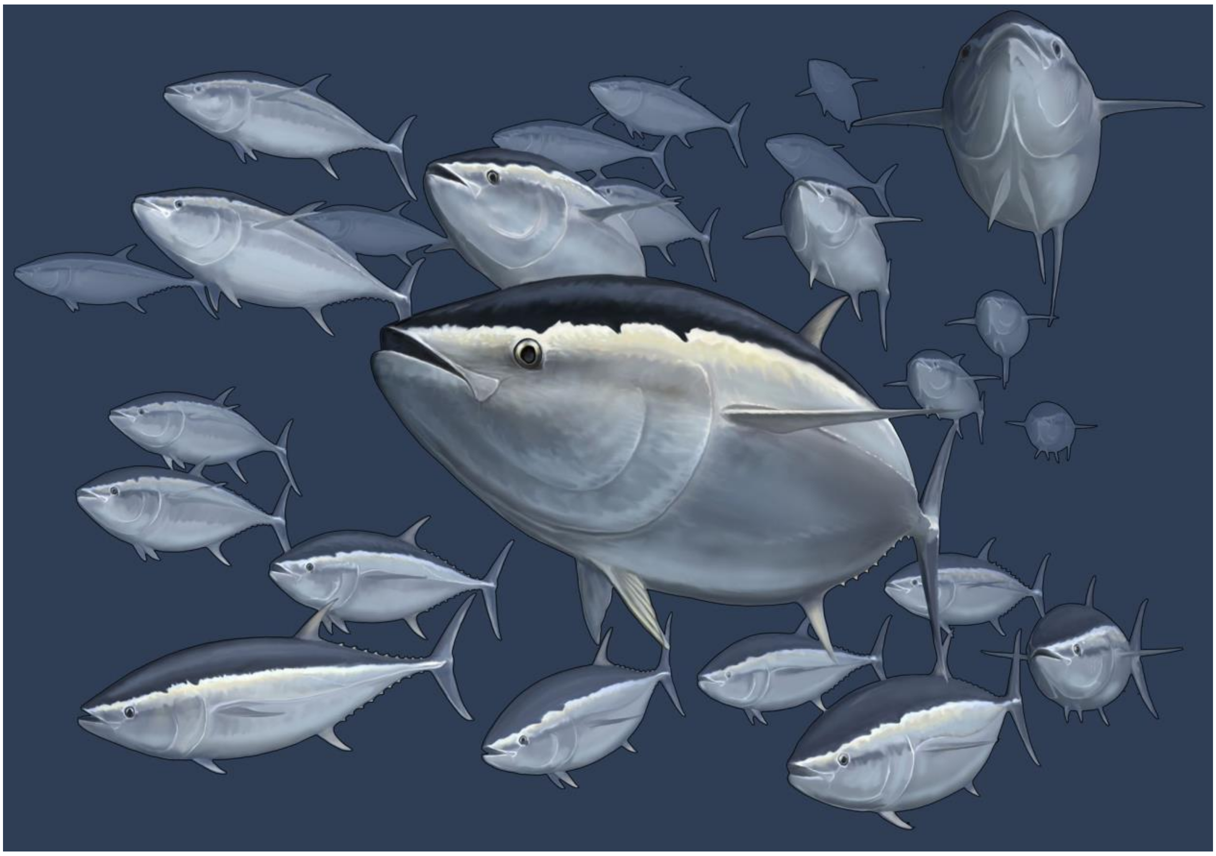
INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS

COMMISSION INTERNATIONALE POUR LA CONSERVATION DES THONIDES DE L'ATLANTIQUE

COMISIÓN INTERNACIONAL PARA LA CONSERVACIÓN DEL ATÚN ATLÁNTICO



ATLANTIC-WIDE RESEARCH PROGRAMME FOR BLUEFIN TUNA

(ICCAT GBYP)

PHASE 6

EC GRANT AGREEMENT SI2.727749

GBYP SCIENTIFIC AND TECHNICAL FINAL REPORT FOR PHASE 6

April 12, 2017

ICCAT – Calle Corazón de Maria 8, 6° - 28002 Madrid – España

ATLANTIC-WIDE RESEARCH PROGRAMME FOR BLUEFIN TUNA (ICCAT GBYP)

PHASE 6

FINAL REPORT

INDEX

EXECUTIVE SUMMARY……………………………………………………………………………………… 4
1. Introduction…………………………………………………………………………………………… 6
2. Coordination activities……………………………………………………………………………...... 9
2.1 Second external review of the Programme……………………………………………………………… 10
3. Data mining and data recovery………………………………………………………………………. 11
3.1. Objectives of the data recovery and data mining……………………………………………………… 11
3.2 Data recovery……………………………………………………………………………………………… 12
3.3 Electronic tag data recovery……………………………………………………………………………… 14
3.4 Trade, auction and marked data further elaboration……………………………………………………… 15
3.5 Support to Mauritania……………………………………………………………………………………… 18
3.6 BFT Data Preparatory Meeting…………………………………………………………………………… 18
4. Aerial Survey on Bluefin Tuna Spawning Aggregations……………………………………………… 19
4.1 Objectives and overview of the aerial survey for bluefin tuna spawning aggregations……………………………………………………………………………………… 19
4.2 Suspension of the aerial survey in Phase 6……………………………………………………………… 22
5. Tagging activity……………………………………………………………………………………... 23
5.1 Objectives…………………………………………………………………………………………………… 23
5.2 Tags and correlate equipment……………………………………………………………………………… 24
5.3 Tagging activities…………………………………………………………………………………………… 24
5.4 The analysis of the PSAT tags data……………………………………………………………………… 28
5.5 The analysis of displacements of tagged BFT…………………………………………………………… 29
5.6 Tag awareness campaign…………………………………………………………………………………… 31
5.7 Tag reward policy…………………………………………………………………………………………… 32
5.8 Tag recovery and tag reporting…………………………………………………………………………… 32
5.9 Close-kin genetic tagging…………………………………………………………………………………… 36
6. Biological Studies……………………………………………………………………………………… 38
6.1 Objectives…………………………………………………………………………………………………… 39
6.2 Activities……………………………………………………………………………………………………… 41
6.3. Sampling……………………………………………………………………………………………………… 42
6.4. Analyses……………………………………………………………………………………………………… 42
6.4.1 Otolith chemistry…………………………………………………………………………………………… 42
6.4.1.1 Determining nursery origin of BFT captured in potential mixing zones…………………………… 42
6.4.1.2 Individual origin assignment……………………………………………………………………………… 44
6.4.1.3 Discrimination of nursery areas within the Mediterranean Sea by trace element and stable isotope composition in young-of-the-year bluefin tuna and origin assignation of individuals from Bay of Biscay ……………………………………………………………………………………… 45

6.4.2. Genetics………………………………………………………………………………………… 48
6.4.2.1 Origin assignment of juveniles and adults captured at feeding aggregations throughout the Atlantic and over different years ……………………………………………………………… 48
6.4.2.2 Microsatellite genotyping of reference samples in the Mediterranean………………………… 48
6.4.3. Otolith shape analyses……………………………………………………………………… 53
6.4.4. Integrated approach to stock discrimination……………………………………………… 56
6.4.5 Age determination analyses……………………………………………………………… 58
6.4.6 Larval studies………………………………………………………………………………… 60
7. Modelling approaches…………………………………………………………………… 61
7.1 Objectives………………………………………………………………………………………… 61
7.2 Phase 6 activities for modelling in support of BFT stock assessment……………………… 62
7.1 Modelling technical assistant……………………………………………………………… 63
7.2. ICCAT GBYP Core Modelling MSE Group………………………………………………… 64
7.3 VPA Training course………………………………………………………………………… 66
8. Legal framework………………………………………………………………………… 67
9. Cooperation with the ICCAT ROP……………………………………………………… 68
10. Steering Committee Activities………………………………………………………… 68
11. Funding, donations and agreements………………………………………………… 69
12. GBYP web page………………………………………………………………………… 72
Annex 1. List of reports and scientific papers in GBYP Phase 6…………………………… 73
Annex 2. GBYP contracts issued in Phase 6…………………………………………………… 81
Annex 3. List of meetings attended by GBYP coordination staff in Phase 6……………… 82

ICCAT ATLANTIC-WIDE RESEARCH PROGRAMME FOR BLUEFIN TUNA (GBYP)

FINAL REPORT FOR PHASE 6 (2016-2017)

EU GRANT AGREEMENT SI2.727749

EXECUTIVE SUMMARY

The Atlantic-wide research programme on bluefin tuna (GBYP) officially began on October 2009, but it was practically initiated on March 2010. The Phase 6 of GBYP activities began on 21 February 2016 and ended on 20 February 2017, including (a) continuation of data mining, recovery and elaboration, (b) biological studies, (c) tagging, including awareness and rewarding campaign, and (d) further steps of the modelling approaches.

In the first part of this Phase, following the ICCAT Commission decision, a second independent review of the ICCAT GBYP programme was carried out. The reviewers provided an extensive and detailed analysis of the work done from 2010 to 2016 and a range of proposals for improving the research in the following years. The reviewers recognized the important improvements in scientific knowledge obtained by the ICCAT GBYP in the first parts of the programme. Specifically, the reviewers pointed out that "The GBYP is a success and should be continued".

Data recovery activities continued in the Phase 6 with the exhaustive analysis of the ancient trap data. Additionally, new data sets were provided, including recent Mediterranean long line data from Italy, ancient trap data from Italy and from the Kingdom of Aragon, and old data from the Canary Islands. The datasets were incorporated into the ICCAT database and the SCRS has already been informed of this progress. In order to assess possible removals of BFT by year, an external contract was provided for a further analysis of the trade, auction and marked data (3 datasets obtained during the previous phases). The analysis revealed that, although generally below Task 1 catch data, the results should be considered to represent underestimate of total catches, mainly due to the gaps in each of the three datasets. In order to improve knowledge of BFT movements and behaviour in its distribution area and with the special aim to provide data to the stock assessment MSE process, numerous electronic tags datasets were recovered from entities out of the GBYP. For the purpose of enhancing BFT data collection in the Islamic Republic of Mauritania, a short training course was held in Nouadhibou.

In this Phase, the aerial survey on spawning aggregations, which was included in the initial plan, was suspended according to the decision of the Steering Committee and the funds were reallocated for enhancing other activities.

The tagging strategy in Phase 6 again addressed all the tagging activities to the electronic tagging, while the conventional tagging activity was limited to complimentary ones. This year the electronic tags were deployed in Moroccan, Sardinian and Portuguese traps, in Turkish purse seiners and by hand line in the Strait of Messina. A total of 92 pop-up tags were deployed in the year 2016 and most of the results are already available. The 192 relevant datasets obtained in earlier years were reprocessed in order to obtain the enhanced geolocation estimates (according to the latest algorithm) and to have a unique track processing methodology and comparable results. For the purpose of improving the tag recovery results, a special tag awareness activity was carried out this year. Short informative videos and spots on tagging activities were produced in eight languages and widely distributed. The recovery activities were also continuously carried out in this phase and the tag recovery rate was finally over the 2%. The refinement of the first part of the scoping study on close-kin mark-recapture genetic tagging

was carried out and a technical guide was provided for possibly organizing a CKMR genetic workshop.

The large participations of scientific institutions to the biological studies keeps on, providing many interesting results. The sampling of adult bluefin tuna was carried out on various farms this year and it was very successful, while the sampling for juveniles encountered various problems, mostly due to unfavourable oceanographic conditions and a very peculiar situation of the distribution of YOY. Nevertheless, a high number of various types of samples (tissues, spines, otoliths) was collected in different areas. Several types of microchemical and genetic analyses were completed, as well as additional otolith shape analysis and age determination. For the first time, a genetic analysis of microsatellites was performed in parallel with SNPs analyses, with the objective of confirming the results. The analysis of the bluefin tuna in the mixing zones in central and eastern Atlantic showed again a considerable interannual variability in the degree of mixing between WBFT and EBFT, which seems much more important that previously known. ICCAT GBYP held an international workshop for BFT larval studies and surveys for the purpose of exchanging knowledge in this field and examine the possibility for inclusion of larval index into the Bluefin tuna stock assessment trials.

As concerns the modelling approaches, the existing contract for the expert modelling assistant was extended to Phase 6 with the objective to continue the work already initiated in previous Phases. In this Phase, the Steering Committee recommended to suspend the contract for the modelling coordinator, who will be substituted by a modelling communicator in the following Phase. A third meeting of the ICCAT GBYP Core Modelling MSE Group was held in November 2016. The ICCAT GBYP Modelling MSE Group is already using all GBYP electronic tag data and the main results of the GBYP biological studies. A final version of the operating model (M3 v1.3) was designed following the feedback from the Core Modelling Group and it was simulation tested. The trial document was also updated following the Core Modelling Groups inputs. A special software package (R-ABTMSE) was developed, allowing simple and rapid design of operating models, fitting of operating models to data, design of management procedures, specification of performance metrics and the running of MSE. For the purpose of improving the current modelling capacities for stock assessment, in February 2017 a short training course on VPA was organised for the 11 participants from various countries, for enhancing their capabilities with the assessment tools.

As a matter of fact, even in this difficult Phase, the GBYP is fulfilling all its obligations, reaching almost all objectives as planned, besides the operational constraints, the changes in strategy and the limited availability of funds, which reached so far only about 60% of the approved budget for the same period of time; the annual GBYP report provided to the SCRS and the Commission shows both the budged used for each activity and the results obtained so far, against the initial figures. The problem of ensuring a stable funding was raised again by the Steering Committee, but so far it was not possible for the Commission to find an agreed solution for this problem, which is particularly relevant for a multiyear research programme such us the GBYP, also taking into account the agreed extension up to 2021.

KEYWORDS

bluefin tuna, ICCAT, historical data, biological analyses, tagging, genetics, microchemistry, otolith shape, modelling, Mediterranean Sea, Atlantic Ocean.

1. Introduction

The ICCAT Atlantic-wide Research Programme for Bluefin Tuna was officially adopted by SCRS and the ICCAT Commission in 2008, and it started officially at the end of 2009, with the objective to:

a) Improve basic data collection, including fishery independent data;
b) Improve understanding of key biological and ecological processes;
c) Improve assessment models and provision of scientific advice on stock status.

Since the beginning, the Programme was conventionally identified with the acronym GBYP (Grand Bluefin Year Programme), for showing the ideal continuation of the previous multi-year ICCAT BYP.

The total budget of the programme officially approved by the ICCAT Commission in 2008 was 19,075,000 Euro in six years, with the engagement of the European Union and some other ICCAT Contracting Parties to contribute to this programme in 2009 and in the following years. The initial year had costs for 653,874 Euro (against the original approved figure of 890,000 Euro), the second phase had costs for 2,318,849 Euro (against the original figure of 3,390,000 Euros), while the third phase had costs for 1,769,262 Euro (against the original approved figure of 5,845,000 Euro). The fourth phase had a total budget of 2,875,000 Euros (against the original approved figure of 5,195,000 Euros) and final costs for 2,819,556 Euro. The fifth phase had a total budget of 2,125,000 Euros (against the original approved figure of 3,345,000 Euros) and final costs were 1,995,787 Euros. The sixth phase has a total budget of 2,125,000 Euros (against the original approved figure of 410,000 Euros) [1]. The overall ICCAT GBYP operating budget for the first six phases, covering seven years (a total of 11,869,782 Euros) is about 62.23% of what it was supposed to be (the 19,075,000 Euros approved by the Commission). These sequential budget reductions had an obvious impact on all activities carried out so far. Several private or public entities[2] provided few additional funds or in kind support (see Section 11 of this report for the details).

Phase 1 (EU Grant agreement SI2.542789) and Phase 2 (EU Grant agreement SI2.585616) activities were jointly committed by the European Community (80%), Canada, Croatia, Japan, Libya, Morocco, Norway, Turkey, United States of America, Chinese Taipei and the ICCAT Secretariat. Other CPCs (Algeria, Egypt, Iceland and Korea) joined the first funders in the following Phases, while Phase 6 was co-funded by the United States, Japan, Tunisia, Turkey, Libya, Morocco, Norway, Canada, Albania, Korea, Chinese Taipei, Popular Republic of China and Iceland, in order of contribution. Some CPCs did not pay their contribution (even requested or committed), further limiting the use of available funds, because the EU has a maximum percentage of contribution of 80% under the firm condition to duly obtain the remaining 20%.

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[1] The final cost of Phase 6 (which is lower than the operating budget) will be showed in the administrative report, due to the late arrival of some invoices.

[2] For the full list, see chapter 11 of this report.

The third phase (7 months) officially initiated on June 20, 2012, after the signature of the Grant Agreement for co-financing the GBYP Phase 3 (SI2.625691) by the European Commission. Phase 3 officially expired on January 19, 2013, but closing the administrative issues took more time than scheduled, due to a delay of one contractor in providing the necessary documents. The GBYP activities up to the first part of Phase 3 were presented to the SCRS and the ICCAT Commission in 2012 and they have been approved, while the last part was present to the SCRS and the Commission in 2013 (documents SCRS/2013/144) and therefore approved.

The fourth phase of GBYP officially initiated on March 6, 2013, after the signature of the Grant agreement for co-financing the GBYP Phase 4 (SI2.643831) by the European Commission and then it was extended for a total of about 23 months, ending on 23 February 2015. The partial results were presented to SCRS and the Commission in 2013 and 2014 (documents SCRS/2013/144 and SCRS/2014/051) and they have been approved, while the final results were presented to the SCRS and the Commission in 2015 (documents SCRS/2015/144 and SCI/2015/APP.5), they were approved by the SCRS and endorsed by the Commission.

The fifth phase of GBYP was officially initiated on February 24, 2015 after the signature of the Grant agreement with the European Union for co-financing the GBYP Phase 5 (SI2.702514) by the European Commission and ended on 23 February 2016. The partial results were presented to the SCRS and the Commission in 2015 (documents SCRS/2015/144) and they have been approved. The final report for Phase 5 has been officially approved by the European Union, while the final results were presented to the SCRS and the Commission in 2016 (documents SCRS/2016/193) and were therefore approved.

The sixth phase of the ICCAT GBYP officially started on 21 February 2016 following the signature of the Grant agreement for the co-financing of the ICCAT GBYP Phase 6 (SI2.727749) by the European Commission and expired on 20 February 2017. The Grant agreement was revised on February 6, 2017, taking into account the modification of the activities as recommended by the Steering Committee. A first report of the GBYP activities in Phase 6 up to September 2016 was provided to the SCRS and the Commission (SCRS/2016/193; **Annex 1b, documents no. 17**); the activities were approved by the SCRS and endorsed by the Commission. The final report of Phase 6 activities will be submitted to SCRS and at the Commission in their respective meetings in 2017.

All final reports of all GBYP activities in Phase 6 have been provided to the ICCAT GBYP Steering Committee and published on the ICCAT GBYP web pages (http://www.iccat.int/GBYP/en/)

The ICCAT GBYP activity is being supported by a twin programme carried out by NOAA-NMFS, which will focuses its research activities on the western Atlantic Ocean.

The ICCAT Commission, in its meeting in Genova (Italy) on November 2014 approved the extension of the GBYP up to 2021 as included in the SCRS report, following the recommendations of the GBYP Steering Committee and the SCRS. A new plan for the GBYP activities to be done during these additional years was approved along with the extension.

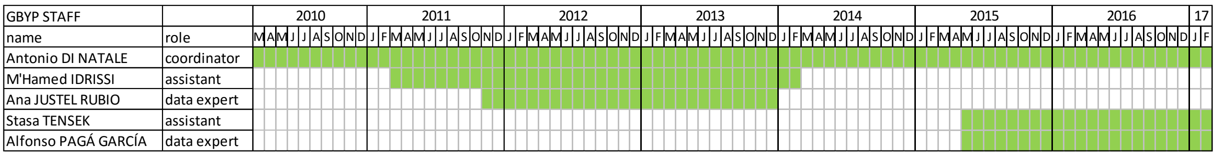
For the purpose of independently reviewing the work carried out to date within the scope of ICCAT GBYP and evaluating the effectiveness of this complex research programme, as required by the Commission in 2015, a large comprehensive review of the first five Phases of ICCAT GBYP was carried out at the beginning of the Phase 6 and the results were presented to the SCRS 2016 Plenary and to the Commission at its 2016 Special Meeting.

Some thoughts on the future of the ICCAT GBYP were presented by three Steering Committee Members as a scientific document SCRS/2016/211 which is attached in **Annex 1b, document no. 21.** The paper concentrated on identification of the priorities in a present and future BFT research and a possible role of the GBYP within; this document also provided some recommendations regarding institutionalizing of the programme including funding.

2. Coordination activities

Besides the first 11 months of the GBYP, when the Coordinator was acting alone, since Phase 2 of the Programme, the staff was composed by the GBYP Coordinator, the Coordinator assistant (up to February 2014) and one contracted technician for data management (up to 2 January 2014). In the second part of Phase 4, because of budget constraints and other reasons, the staff was reduced to the Coordinator only, while the previous staff level was resumed on May 2015. The Coordination assistant is now Mrs. Stasa Tensek, while Mr. Alfonso Pagá García is in charge of the data bases and the tags register. The GBYP staff history is showed on **Table 1**. The ICCAT Secretariat provided the necessary support for the GBYP activities.

Table 1. ICCAT GBYP staff over the different years of the programme.



A total of **51 reports** were produced in the framework of ICCAT GBYP in Phase 6 (**Annex 1a**). Several additional documents and reports have been also provided by GBYP for the needs of the Steering Committee for its meetings. A total of **50 scientific papers** have been produced in Phase 6 (list in **Annex 1b**), while others will be published in the following months. The copies (1613 pages) are in separate volumes (separate Annex 1a, volumes 1 and 2, and Annex 1b, volumes 1 and 2, to this report). So far, the GBYP produced in total, over the first 6 Phases, **247 activity reports** and **221 scientific papers**.

A total of 8 Calls for Tenders, and 3 official invitations were released in Phase 6, along with 1 call for applications to the training course. A total of 20 contracts have been awarded to various entities (**Annex 2**). In total, the number of contracts provided by GBYP in the first 6 Phases is 111, including 91 entities, localised in 23 different countries; many hundreds of researchers and technicians have been working so far in the various GBYP activities; this large and open participation to ICCAT GBYP activities is considered to be one of the best results of this research programme. The coordination staff participated in 10 meetings in Phase 6 (**Annex 3**).

As usual, the administrative and desk work behind all these duties was huge and heavy and it was carried out in continuous and constructive contact with the ICCAT Secretariat and the Administrative Department, which had to face an important additional workload caused by all GBYP activities since the beginning of this programme, as well as the ICCAT Statistical Department.

Some delays in Phase 6 have been caused by several changes in the previously agreed strategy, particularly by the lack of agreement among the members of the Steering Committee in several cases. Almost all delays were promptly recovered by the GBYP coordination with additional work.

Furthermore, the GBYP coordination is providing scientific support to all the national initiatives which are potentially able to increase the effectiveness of the GBYP and its objectives. For this reason, since 2010 the Coordinator joined the Steering Committee for the bluefin tuna programmes of the NOAA, together with some members of the GBYP Steering Committee; in this function he participated to the evaluation session of the US domestic research programmes for bluefin tuna also in 2012, 2013, 2014, 2015 and 2016.

The budget items included under the GBYP Coordination activity in Phase 6 were: Coordination staff salaries and benefits, Travel and subsistence (including SC), Computer hardware and software, Consumables and supplies, Contract for external SC member, contracts for the external review, ICCAT Secretariat overhead and ICCAT staff. The original budget for the Coordination activity was 390,000.00 euro and it was reduced to 383,000 euro after the amendment.

In conformity with the Atlantic-Wide Bluefin Research Programme (GBYP) adopted by the SCRS and the Commission for Phase 6 in 2015, as it was modified by the GBYP Steering Committee in 2016, the following research initiatives have been conducted or initiated (see also **Annex 2**).

2.1 Programme Review

The second review of ICCAT GBYP was carried out in the first part of Phase 6. After a selection, the contract was provided to MRAG (UK). The independent reviewers have been Ph.D. Michael Sissenwine and Ph.D. John Pearce; the report was made available to the SCRS and the Commission (**Annex 1a. document no. 2**, provided also as SCRS/2016/192).

The reviewers provided an extensive and detailed analysis of the work carried out from 2010 to 2016 and range of proposals for improving the research in the following years.

The reviewers recognized the important improvements in scientific knowledge obtained by the ICCAT GBYP in the first parts of the programme. Specifically, the reviewers pointed out that “The GBYP is a success and should be continued. Advances in biological methods (genetics, otolith microchemistry and shape) to determine spawning ground origin of bluefin tuna are particularly successful.” and that “The GBYP has successfully advanced methods for determining the stock origin (eastern or western spawning grounds) of bluefin tuna found throughout the Atlantic Ocean. It has retrieved data that give a historical perspective (including ancient history) on fisheries and improved some time series of data that are used in stock assessments. Model development is going well such that it is reasonable to expect mixed spawning stock BFT fisheries advice in the future (thus addressing need 1 on mixing). Modelling can also be used to guide future research priorities and to quantify data collection priorities. These successes justify the GBYP and the potential for transitioning them into operational data streams to support future scientific advice and management is reason enough for continuing the program”.

3. Data mining and data recovery

3.1. Objectives of the data recovery and data mining

The objective of data recovery and data mining activities is to fill the many gaps existing in several data series currently present in the ICCAT data base, concerning both recent and historical data, which causes a large amount of substitutions in the assessment process, increasing uncertainties. At the same time, data mining activities should provide reliable data series, longer that those currently available, recovering data from many sources, including archives having difficulties for the access. The data mining activity can include also the recovery of old genetic and biological data. This activity allows for a better understanding of the long-time catch series by gear, improving the data available for the assessment and possibly for replacing substitutions used for data gaps; old data will allow also for a better understanding and for improving our knowledge about Atlantic bluefin tuna. The data recovered so far in all ICCAT GBYP Phases are showed in **Table 2** and **Table 3**, according to the last data and revision. The GBYP was also very active for organising the SCRS BFT Data Preparatory meeting in 2016 (**Annex 1a, document no. 1**), cooperating with the ICCAT Secretariat.

Table 2. Total data recovered by GBYP from Phase 1 to Phase 6.

TOTAL PHASES 1 to 6	origin	data	total data
# Records	OG	92.802	490.018
	TP	35.704	
	TAMD	311.415	
	FARM	49.364	
	HGEN	733	
BFT (no.)	OG	59.887	27.732.489
	TP	26.618.277	
	TAMD	1.004.228	
	FARM	49.364	
	HGEN	733	
BFT (tons)	OG	121.967	1.381.474
	TP	1.178.624	
	TAMD	80.408	
	FARM	475	
	HGEN	-	
# BFT sampled (size and/or weigth or historical genetics)	OG	105.986	989.158
	TP	7.610	
	TAMD	825.485	
	FARM	49.364	
	HGEN	713	

Legend: OG = Other Gear; TP = Trap; TAMD = Trade, Auction and Market Data; FARM = Farmed tunas; HGEN = Historical Genetic samples;

Table 3. Total data recovered by GBYP from Phase 1 to Phase 6 by century (<1500-1900) and by decade (1900 onwards).

TOTAL PHASES 1 to 6																		
DATA TYPE	Year / source	<1500	1500	1600	1700	1800	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
# Records	OG						9	10	222	13.518	105	15.822	30.212	18.264	1.905	1.174	10.197	1.364
	TRAP		302	767	538	6.221	3.005	4.360	6.727	2.301	1.188	1.021	1.040	2.032	780	3.868	1.554	
	TAMD																249.132	62.283
	FARM															851	18.492	30.021
	HGEN	145						110	155			2			30			291
BFT (no.)	OG													204	42	9.937	28.199	21.505
	TRAP		4.097.464	3.265.900	898.029	4.511.248	1.613.889	1.883.967	2.971.685	2.013.583	1.002.661	1.787.209	1.566.956	614.611	70	204.806	186.199	
	TAMD														178.743		660.388	165.097
	FARM															851	18.492	30.021
	HGEN	145						110	155			2			30			291
BFT (tons)	OG						44	163	601	2.497	6.056	6.057	29.059	14.492	17.880	17.086	26.848	1.184
	TRAP		10.892	227.161	78.819	148.173	40.327	72.010	76.801	83.592	127.009	86.204	111.417	71.873	8.761	19.568	15.306	711
	TAMD																64.326	16.082
	FARM															207	268	
	HGEN																	
# BFT sampled (size and/or weigth or historical genetics)	OG												18.614	18.548	804	18.569	34.365	15.086
	TRAP							153	170							2.225	5.062	
	TAMD																660.388	165.097
	FARM															851	18.492	30.021
	HGEN	145						110	155			2			10			291

Legenda: OG = Other Gear; TRAP = Tuna Trap; TAMD = Trade, Auction and Market Data; FARM = Farmed tunas; HGEN = Historical Genetic samples

3.2 Data recovery

ICCAT GBYP issued one Call for Tenders under this activity in Phase 6, awarding 3 contracts. One contract was for recovering recent long-line data (by area, vessel, day, effort, and catch in kg and number, length and weigh individual frequencies), a second one for additional recent long-line data with the same details and for additional historical trap data, and a third one for trying the recovery of historical catch data in the Canary Islands zone. No proposals have been received from other ICCAT areas.

In the second part of the Phase, GBYP discovered that an important Ph.D. thesis was carried out on tuna traps in the Kingdom of Aragon at the University of Tarragona in 2015 and many of these traps are not in the ICCAT GBYP historical data sets. After a recommendation of the Steering Committee, it was decided to provide an invitation the author and, following a positive response, a direct contract was awarded for recovering these additional datasets.

LL and TRAP bluefin tuna data recovered in Phase 6 account for a total of 2,666,971 kg and 13,264 fish, while the data from the Canary Islands concerns a total of 36,877 kg of bluefin tuna, but many data needs a further analysis, because most are related to not-well defined tuna species. All data were provided on the Excel forms, in the format used by the ICCAT Statistical Department.

The data sets recovered from Mediterranean LL for the years 2002-2015 (which are additional data sets not already available in the ICCAT data base) include catches by vessel, area and day, partly with effort data (no. of hooks/day) and are related to a total catch of 11,070 bluefin tunas and a total weight of 112,875 kg. In addition, 11,059 bluefin tunas have individual length or weight or both.

The data sets recovered for ancient Italian traps for the period 1823-1922 were extracted from additional documents recently discovered and they fill some temporal gaps in already existing data series, for 13 traps. The data varies from trap to trap, from daily catches by fishing operation ("mattanza" to total year catch). The trap data are related to only 8,463 bluefin tuna in number, and 2,554,096 kg, because in most of the cases, only the total catch in weight was recorded on the original documents. The difficulties for recovering these data was considerable. These data sets for long lines and historical traps are additional to those already recovered in previous GBYP Phases. Data recovered in Phase 6 from longliners (LL) and traps (TRAP) in Italy are shown on **Table 4**.

Table 4. Data recovered in Phase 6 from Italian longliners (LL) and traps (TRAP).

Fishing period	Gear	Fishing area	BFT total catch n	BFT total catch kg	BFT Samples (FL and/or weight	Number of vessels
2002-2015	LL	Adriatic Sea	1952	92310.4	1952	3
2002-2015	LL	Strait of Sicily	2417	112875	2417	22
2002-2015	LL	Tyrrhenian Sea	6690	340964.5	6690	6
2013-2015	LL	Sardinia	11	1097.1		1
1823-1836	TRAP	Marzamemi	1638	44099		
1918-1922	TRAP	Scopello		366220		
1918-1922	TRAP	Castellammare del Golfo		195700		
1918-1922	TRAP	Magazzinazzi		626900		
1920-1922	TRAP	Orsa	556	10700		
1922	TRAP	Isola delle Femmine		21900		
1922	TRAP	Mondello		64300		
1920-1922	TRAP	Vergine Maria		7077		
1918-1922	TRAP	S. Elia		267900		
1918-1922	TRAP	Solanto		463600		
1918-1922	TRAP	S. Nicolò		173500		
1918-1922	TRAP	Trabia		297700		
1920-1922	TRAP	Torre Caldura		14500		

The data sets recovered in the Canary Islands were extracted from ancient registers of various Spanish factories in Tenerife, La Gomera and Las Palmas, providing various types of data by year, month or even day, sometimes by number of fish and/or weight by specie and by factory. The data recovered are related to various tuna species, to be further analysed in detail, and includes for sure at least a total of 36,877 kg of bluefin tuna catches. A main problem concerns unidentified tuna species related to the number or weight of mixed tuna species which arrived to the salting and canning factories. **Table 5** shows the data for all species in detail. Additionally it was possible to recover information related to the vessels fishing in the Canary area, but was impossible to relate each vessel with their correspondent catch. Catches were possibly obtained by hand lines (HAND) or pelagic trawls (MWT).

Table 5. Data recovered in Phase 6 in salting and cannery factories from handliners (HAND) and mid-water pelagic trawl (MWT) in the Canary Islands.

Factory Name	Fishing Period	Indeterminated Species (n)	Indeterminated Species (kg)	BFT kg	ALB kg	YFT kg	BET kg	SKJ kg
Casanova	1926-1939	1778	545512					95227
Gran Canaria	1966-1984			5773	263995	720522	9030082	5245444
La Rajita	1926-1984	3873	4766308	20995	1408811	171557	6964369	6380551
Novaro	1931-1934	2204	106748					15366
Santiago	1927-1983	5089	1438805	4878	333435	2875	2302941	2035091
Tenerife	1949-1984		339161	5231	62765	391559	2431410	3869455
Trujillo	1927-1934	1485	269698					70110
TOTAL	1926-1984	**14429**	**7466232**	**36877**	**2069006**	**1286513**	**20728802**	**17711244**

The data recovered for the former Kingdom of Aragon comprises the detailed datasets for the several tuna traps located in Sicily, Sardinia, Valencia and Catalonia in the XVI-XVII century. Data were recovered for following traps in Sicily: Favignana, Formica, Bonagia and "Tonnara dell'Ursa"; in Sardinia: Pula, Carbonara, Pixini, Porto Scusso, Porto Palla, Santa Catterina di Pittinuri, Le Saline, Cala Vignola, San March, Porto Pi, Capo Bianco, Cala Agustina, Isola Piana and Argentiera; in Valencia: Benidorm, El Palmar and Xàbia; and for one trap in Catalunia: l`Hospitalet de l'Infant. These traps were elected for the data recovery because not only these series were the most complete and detailed ones, but also because they were among the most productive traps in the area in the examined period.

The final reports of Phase 6 data recovery activities are attached in **Annex 1a, document no. 5, 7, 8 and 12**. An overview of the bluefin tuna data recovery in the first part of the Phase 6 is given in the paper **SCRS/2016/150, Annex 1b. document no. 13**, already presented at the SCRS BFT Intersessional meeting.

3.3 Electronic tag data recovery

The electronic tagging carried out by ICCAT GBYP in previous Phases showed a very high complexity of the bluefin tuna movements and these data, along with the results obtained from the GBYP biological studies, are also showing mixing in areas where it was not demonstrated before. Since the ICCAT GBYP tagging data alone are obviously not sufficient for describing the complexity of movements and behaviour of BFT in its distribution area, either for the short timeframe of GBYP activities or for the limited number of electronic tags deployed so far, the SCRS recommended to recover all available data sets from electronic tags deployed by several institutions in previous years, with the objective to have a comprehensive overview of BFT movements. Several data sets have been voluntary provided so far to the two experts in charge of assembling these data in a homogenous manner (Dr. Matthew Lauretta on behalf of the SCRS BFT Species Group and Dr. Thomas Carruthers on behalf of GBYP Core Modelling MSE Group). These data have been used for "feeding" the MSE process, which is currently under further developed.

Being aware of additional important e-tags data sets, the ICCAT GBYP Steering Committee recommended to release formal invitations for providing these data sets to the GBYP, with the objective of incorporating these additional data in an organized system and providing them to the SCRS and to the GBYP Modelling Expert. Following the invitation, Ph.D. Molly Lutcavage decided to provide the many e-tags data sets she has directly to the experts, without any cost for GBYP, while Ph.D. Michele Deflorio responded that the e-tags data sets will be provided in the future, only after publishing all data, even if these data were collected with EU funds.

Finally, the only contract was awarded to the Stanford University (Prof. Barbara Block), for providing the available electronic tags datasets. Consequently, 392 electronic data sets were provided from the Stanford University Tag-A-Giant (TAG) research program. The tag data files include all meta data, processed tracks, and the raw files from the tags.

All data provided have been transferred to the modelling experts in timely manner and are used for feeding the MSE model. The final report of this activity is attached in **Annex 1a, document no. 9.**

3.4 Trade, auction and marked data validation

As agreed by the SCRS, the part of trade, auction and market data, which were validated by an external expert contracted by the GBYP in Phase 4 (**Figure 1**), were officially considered fully validated, without the need of forming any specific expert group for further data examination, as initially planned.

Data sets, in their original format did not comply with the requirements for the direct incorporation into the ICCAT data base and therefore an additional work needed to be undertaken to modify and adapt them accordingly, in Phase 5. The GBYP Coordination made some minor modifications in the content and modified the format of the data, following the precise instructions and requirements of the ICCAT Statistical Department and provided the processed data to ICCAT, for incorporating them in the ICCAT data base.

The remaining part of the trade, auction and market data sets, which are not considered fully reliable because they were not validated ("form 3" of the sets), are kept in a separate data base, which is not public, and are subject to possible additional validation against statistical documents, BCDs or other support documentation, a work which would need much more additional time and efforts, and that would require the strict cooperation of the CPCs concerned, national experts and the ICCAT Secretariat.

According to the request made by the ICCAT GBYP Core Modelling MSE Group during its last meeting in Monterey, the data coming from the first two data sets that were validated so far, limiting them to those bluefin tunas having RW and GGW individual data and considered reliable, were analysed and submitted by GBYP to the SCRS Bluefin tuna Intersessional Meeting in 2016 (SCRS/2016/142, **Annex 1b, document no. 9**) for improving the size frequencies for the EBFT.

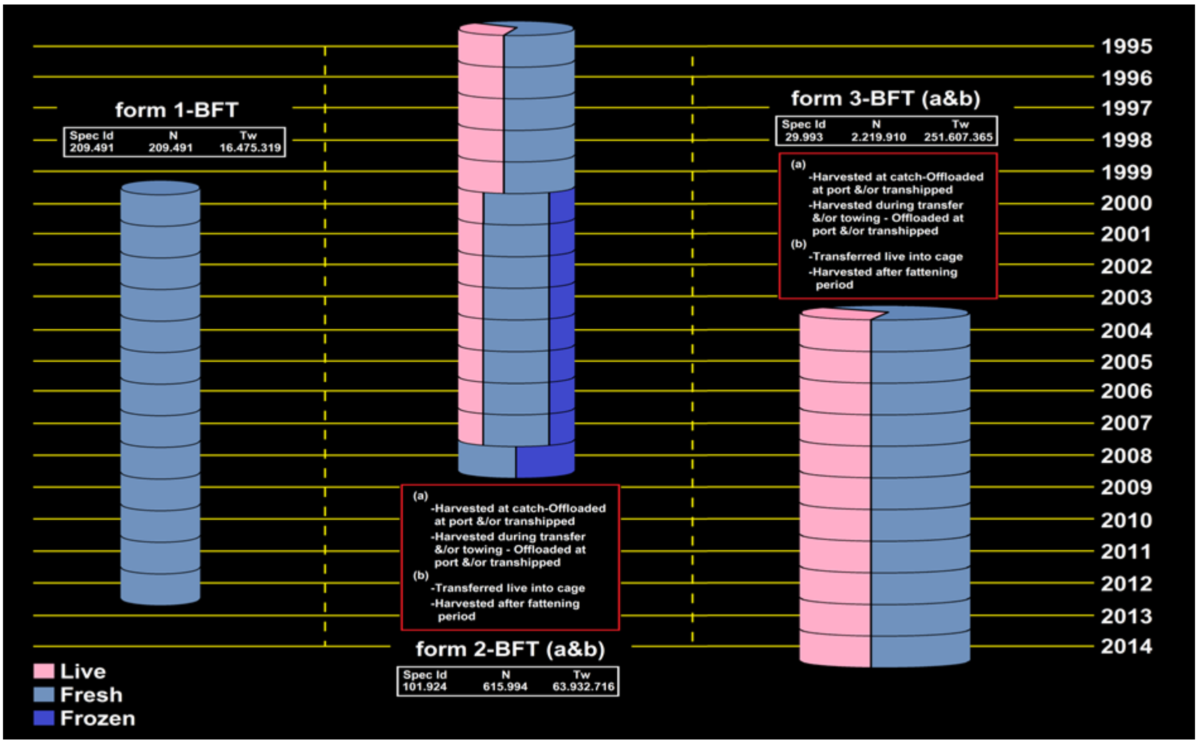


Figure 1. Chronology and structure of trade, auction and marked data (form1, form2 and form3) recovered by GBYP for the period 1995 to 2014.

In July 2016, the ICCAT GBYP Steering Committee, in line with the comments provided by the second external review of the GBYP, recommended analysing all three market data forms for possibly assessing the total removals by year. The SC recommended awarding an external contract for this purpose. In August, a Call for Tenders was released with the goal to re-analyse the market, auction and trade datasets, identify the reliable ones and provide the estimation of the total level of possible catches of Atlantic bluefin tuna that entered into the market for each year covered by the data, ideally by stock and under various hypotheses, including the expected CVs by year, for further analyses of the SCRS BFT Species Group. After selection, a contract was provided to MRAG (UK).

The results from the analysis of all three datasets highlighted differences between the official catch statistics (Task I) used for stock assessment and catch estimates derived from the 3 new datasets (**Figure 2**). Those differences are more evident for the earlier years (before 2008) with estimated catches being much lower than official statistics while they were very close to (but still lower than) Task I data for the recent years. The lack of BCD data before 2008 could be one of the reasons for the higher differences in that period. The analysis also showed that there is considerable ambiguity with regards to records of caged fish as the 3 Forms included a number of records showing fish transferred to cages but with no corresponding records of fish harvested after the fattening period. However, it is not clear whether this is due to records missing from the 3 datasets analysed or if it reflects actual discrepancies.

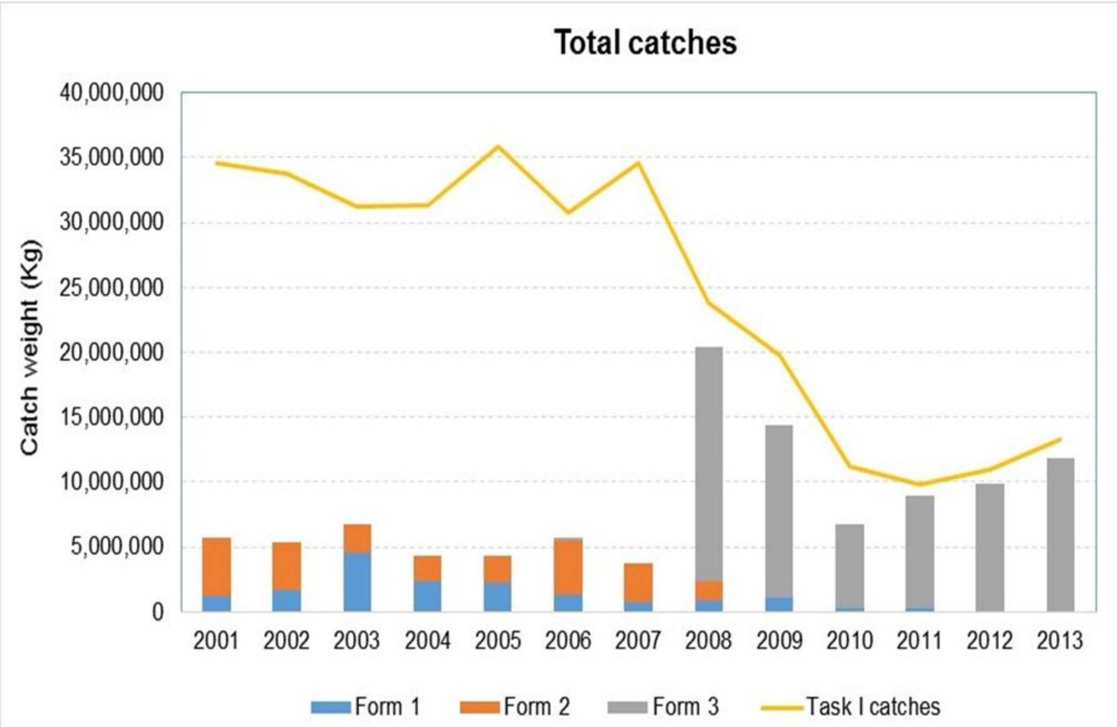


Figure 2. Estimated catches of Eastern Atlantic bluefin tuna as a result of analysis of 3 datasets compared to ICCAT official statistics (Task 1)

The latter issue creates uncertainty in the interpretation of the records and our analysis has provided results under different combinations of data to capture that. Uncertainty in the estimated catches also comes from a number of other sources, including values of fattening ratios and conversion factors and allocation of fish to different fattening groups.

With regards to representativeness, the extent to which each Form captures fishing activity varies but all of them have some gaps in the data they hold. Although the 3 Forms hold data that are largely complementary, gaps still remain even after the 3 Forms are combined (e.g. they do not include catches from Japanese vessels or EBFT fish going to the Japanese market through third-non-EU countries; furthermore, fish going to local markets outside Japan are possibly little represented). For that reason, the results of the analysis are considered to represent an underestimate of total catches. The length distribution frequencies are shown on **Figure 3.**

Full results are available in **Annex 1a, document no. 11**. and as a SCRS paper 2017/013 in **Annex 1b document no. 22**, which has already been presented at Bluefin tuna species group its next meeting in March 2017.

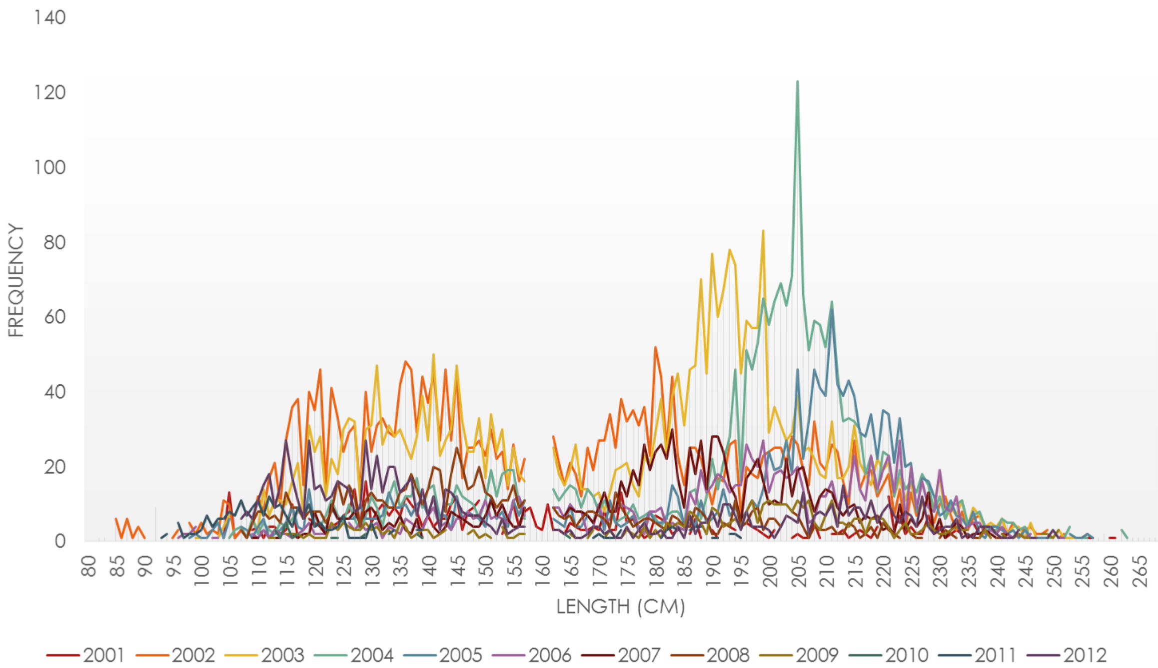


Figure 3. Bluefin tuna length distribution frequencies, as a result of analysis of all 3 forms

3.5 Support to Mauritania

In line with the recommendation of the SCRS, which has been endorsed by the Commission, ICCAT GBYP organized a training course in the Islamic Republic of Mauritania in order to improve data and information collection about bluefin tuna in the area. For that purpose, a memorandum of understanding was signed between the ICCAT Secretariat and the Institut Mauritanien de Recherches Océanographiques et des Pêches. The short course was held in Nouadhibou on 13-14 July 2017 (list of participants is provided in **Annex 1a document no. 14**) and it addressed all the particularities about information and data collection, the reporting according to the SCRS requirements, and how to fill the submission forms, necessary for enforcing the ICCAT Rec. 14-04. All organizative costs, travels and per-diems were covered by the ICCAT GBYP, which also provided dedicated forms and the financial support for the organization of data collection. The report of this activity is attached in **Annex 1a, document no. 13.**

3.6 BFT Data Preparatory Meeting

A Bluefin tuna data preparatory meeting was organised by the SCRS, with the support of GBYP, in Madrid on 25-29 July 2016. The meeting was attended by 40 scientists (plus the ICCAT Secretariat staff), including most of the members of the GBYP Steering Committee and several members of the GBYP Core Modelling MSE Group. The GBYP provided several documents and presentations about the pertinent data that were proposed to the group for consideration. The report of the meeting is attached (**Annex 1a, document no. 1**).

The 2017 Bluefin data preparatory meeting was held in Madrid on 6-11 March 2017. Although formally outside of the Phase 6, that ended on 20 February 2017, it is listed in this Report because the scientific papers presented during the meeting were direct results of the work carried out in Phase 6. Only the scientific documents are here attached (see Annex 1b), while its final report will be attached in the final report of the following Phase because it is not available yet.

4. Aerial Survey on Bluefin Tuna Spawning Aggregations

4.1 Objectives and overview of the aerial survey for bluefin tuna spawning aggregations

ICCAT GBYP Aerial Survey on bluefin spawning aggregations was initially identified by the Commission as one of the three main research objectives of the Programme, in order to provide fishery-independent trends on the minimum SSB. The original GBYP programme included only a total of three annual surveys over a maximum of three different areas, but this plan was later modified by the Steering Committee and the statistical study revealed that under the best possible conditions a very minimum of six surveys will be necessary for detecting a trend with an acceptable CV level. The total original budget, set for 3 surveys in 3 areas, was 1,200,000 euro; the costs for carrying out the first 4 surveys in much more areas (up to 4 main "internal" areas and 7 "external" areas) are about 1,619,624 euro (134.97% of the original budget, but with much more than the double of the activities initially planned). So far, the GBYP objectives initially set for the aerial survey on spawning aggregations in these first Phases have been largely accomplished.

Two surveys on four selected areas have been carried out in GBYP Phase 1 and Phase 2, with many transect replicates. In Phase 2 the protocols were partly changed by the Steering Committee and it was made mandatory the use of bubble windows on all aircrafts. The aerial survey activity was suspended in Phase 3, following the recommendation by the GBYP Steering Committee, because it was requested an extended survey all over the potential Mediterranean spawning areas, which covers about 90% of the Mediterranean Sea surface, and because sufficient funds were not made available.

The extended survey was conducted in 2013 and the results were presented to the SCRS and the Commission. This was the first extended aerial survey conducted in more than 60% of the Mediterranean Sea, under very difficult situations, and using a budget that was not proportionally increased for keeping the same effort on the four main areas; therefore, the replicates in the main areas (defined as "inside") were much less, while they were reduced to the minimum in the additional areas (identified as "outside"). Even in this survey, security and permits problems have been serious constraints.

Due to severe budget constraints, it was impossible to carry out any aerial survey in 2014, during the extension period of Phase 4.

The GBYP Steering Committee, in September 2014, included again an extended aerial survey within the activities of Phase 5; this survey included 7 extended areas and 4 main areas. In the very last part of Phase 4, after the meeting of the GBYP Steering Committee in February 2015, a further analyses of the previous data was requested, for better assessing any variance possibly induced by the use of bubble windows since 2011 and the various types of aircrafts, and the study was included in the final report of GBYP Phase 4 for the EU. The possible use of a calibration exercise was discussed at the same meeting and a first draft on a SWOT analyses was presented by the GBYP coordination (SCRS/2015/143). This preliminary document was therefore discussed by mail with some well-known experts in aerial survey (Dr. Phil Hammond and Dr. Greg Donovan), who shared the contents, and therefore revised and presented to SCRS at the 2015 BFT Species Group meeting. The main results of the SWOT analysis indicates that a calibration for an aerial survey which uses so many pilots and spotters of different nationalities is not feasible, also taking into account the many legal constraints. Furthermore, a calibration limited to the rotation of scientific spotters (when feasible) would concern only one of the many variance factors which can bias an aerial survey. The GBYP Steering Committee, after many discussions, finally confirmed the agreement to include again the extended aerial survey in the activities of Phase 5.

The surface to be surveyed was about 1,284,859 km^2 (312,491 km^2 of “inside” areas and 972,368 km^2 for “outside” areas), representing about 54.35% of the whole surface of the Mediterranean Sea, a surface never covered by any other scientific survey in the Mediterranean so far. Furthermore, this last survey covered about 87.6% of the total potential areas where spawning of bluefin tuna may even occasionally occur. The total length of transects was 25,493 km (14,404 km in “inside” areas and 11,079 km in “outside” areas.

Strong winds, scarce visibility, bluefin tunas travelling well below the surface (many purse-seiners got most of the catches by fishing with sonar in 2015) due to abnormal extreme oceanographic conditions[3] and military activities have been operative and environmental problems that caused troubles for the survey in some areas.

The survey revealed that most of the school sightings were concentrated in the areas initially selected by GBYP for conducting the surveys in 2010 and 2011 (which were also the “inside” areas of the extended survey), confirming the full validity of the initial choice based on scientific knowledge and recent fishery data obtained by a VMS analyses of the purse-seiners activities from 2007 to 2009. Only very few sightings were made in other areas where spawners usually travel not so close to the surface.

Additionally, during the Phase 5, an analyses on overlapping “inside” areas over the four surveys (**Figure 4**) was carried out, because it was supposed that looking at the same areas over the differ years may possibly provide a more homogenous comparison, even if further standardisation might be necessary, because the number of replicates or coverage was different in the various surveys.

There is a large inter-annual variability as well as geographical variability (variable concentrations in variable areas). Overall, pooling all areas together, there is a strong interannual variability both in terms of total weight and

[3] See document SCRS/2015/154, considering that July 2015 was the hottest so far in the Mediterranean Sea in the history of oceanographic records.

density of animals (and taking into account that sub-area G was not surveyed in 2011, the variability may be even larger). In 2010 the total weight (density of animals not being available due to the lack of information that year on cluster size) was almost half as that in 2011, but still much larger than in 2013, but in 2015 we observe the highest total weight of all years, much larger than in 2011. In terms of abundance of animals, 2011 has the larger estimate (and even more considering that area G was not surveyed that year), decreasing to around one third in 2013 (considering only A, C and E) but increasing again to less than two thirds in 2015.

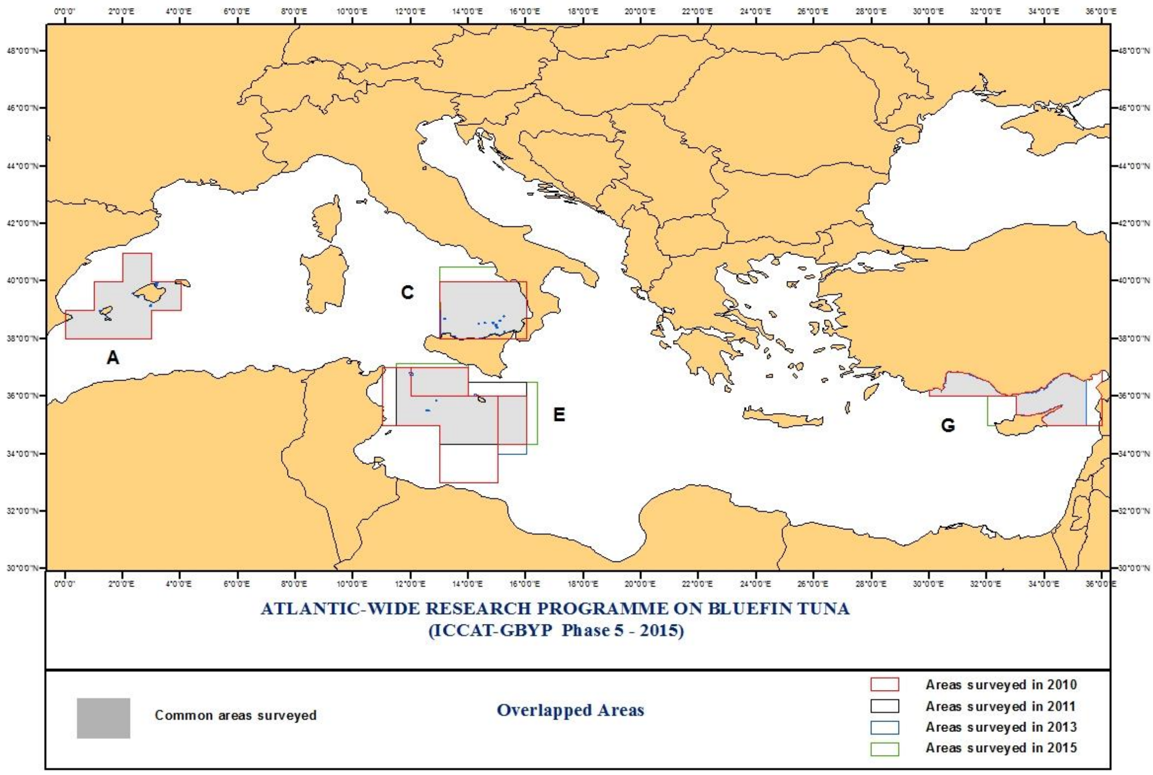


Figure 4. Overlapped Survey blocks for the four GBYP aerial surveys.

Clearly, these are the “normal” variance factors when carrying out an extended survey in a fixed period (which was set according to the peak of bluefin tuna spawning in June, as it is known since a couple of centuries. This effect shold be smoothed in a sufficiently long series of surveys if oceanographic conditions get close to the usual average over most of these years.

In the last part of Phase 5, a power analysis and cost benefit analysis for the aerial survey on spawning aggregations was done in order to have a more focused overview of the works carried out so far within the GBYP and have further details for adopting the best research strategy in Phase 6. The analysis showed that the average cost per km on effort in the GBYP survey was quite low (between 10.14 and 11.23 euro/km) when the survey was carried out only over the main spawning areas, while it increased in a considerable manner when the strategy was turned toward an extended survey covering most of the Mediterranean Sea (from 17.91 to 18.81 euro/km). This relevant increase in the last two extended surveys was due almost exclusively to the extremely complex logistic for surveying the "outside" areas, something that no other survey had faced so far. The comparison of costs with other aerial surveys that have been carried out showed that the GBYP cost (even if the effective transect length was the highest) are the lowest among all recent aerial surveys carried out in the European or Mediterranean area for various marine species.

The main recommendation coming out from the power analysis is that a reduction of the coefficients of variations, at several levels (encounter rates, school size, detection function and additional variances) is required to be able to detect trends in population abundance within an acceptable time frame. Furthermore, increased coverage in terms of kilometers of tracks (which means several replicates) on effort should be necessary. Tables of different cost analysis and power analysis have been provided for the purpose of evaluating the level of power (and therefore coverage) that could be achieved in the future aerial surveys, in correlation with the available level of financial resources.

The results of the aerial surveys carried out so far are available on http://www.iccat.int/GBYP/en/asurvey.htm .

4.2 Suspension of the aerial survey in Phase 6

According to the decision of the ICCAT GBYP Steering Committee adopted by e-mail, the aerial survey for the spawning aggregations was suspended again in the year 2016. The Steering Committee based the decision on the assumption that the financial resources are not sufficient for carrying out an adequate survey (i.e. in terms of survey effort that would be required to achieve a reasonable CV) again on the entire or in most of the area in the Mediterranean Sea where spawners/adults may occur. Additionally, it pointed out large logistical, political and administrative constraints that would more than likely prevent such an extended survey from being adequately implemented, even if very much larger financial resources were available. The summary of the reasons for the suspension of the aerial survey by the Steering Committee in the Phase 6 is in **Annex 1a, document no.3, Appendix 5.**

Later, the Steering Committee identified the potential alternative to conduct a comprehensive survey restricted to relatively limited areas within the Mediterranean that can be adequately surveyed with the available resources. In order for this approach to provide a useful index of abundance, the proportion of the adult stock within the survey areas during the survey needs to be relatively constant. This is essential so that changes and trends in the actual size of the population can be distinguished from inter-annual variability in the utilization of the areas being surveyed. It also reiterated the request that a sort of calibration should be useful. The SC considered the recommendation that this alternative be adopted and the surveys be restricted to the four core overlapping areas that had been included in all the four previous surveys.

The external reviewers of the GBYP, in Phase 6, also acknowledged the many efforts and the low cost of the GBYP aerial survey, along with the constraints and limits. They also recommended to continue the survey on the four main areas as the only possible alternative to a future Close-kin Genetic Tagging for providing a fishery-independent index.

5. Tagging activity

According to the general programme, after the adoption of the ICCAT GBYP Tagging Design and GBYP Tagging Manual in Phase 1, it was planned to begin the tagging activity in GBYP Phase 2 and continue it in the following Phases. The tag awareness and recovery programme was also launched in Phase 2 and continued in the following Phases, including a new tag rewarding policy.

5.1 Objectives

The specific objectives of the GBYP tagging activity on the medium term were set as follows:

a) Validation of the current stock status definitions for populations of bluefin tuna in the Atlantic and Mediterranean Sea. If the hypothesis of two stock units (eastern and western stocks) holds, the tags should provide estimates of mixing rates between stock units by area and time strata (ICCAT main area definitions and quarter at least). It is also important to consider possible sub-stock units and their mixing or population biomass exchange, particularly in the Mediterranean Sea[4] (this point included both conventional and electronic tagging).
b) Estimate the natural mortality rates (M) of bluefin tuna populations by age or age-groups and/or total mortality (Z) (this point was related to conventional tagging).
c) Estimate tagging reporting rates for conventional tags, by major fishery and area, also using the observer programs currently deployed in the Mediterranean fisheries (ICCAT ROP-BFT).
d) Evaluate habitat utilization and large-scale movement patterns (spatio-temporal) of both the juveniles and the spawners (this point was mostly related to electronic tagging but not only).
e) Estimate the retention rate of various tag types, due to contrasting experiences in various oceans.

Electronic Pop-up tags should provide data over a short time frame, while conventional tags, internal archival tags and PIT tags should provide data over a longer period of time, always depending on the reporting rate.
The initial, short-term GBYP objective was to implant 30,000 conventional tags and 300 electronic tags in three years in the eastern Atlantic, with a total budget of 9,765,000 euro; the absolutely necessary tagging design study and protocol, as well as the tag awareness and rewarding campaigns, were not included in this initial budget. So far, with only 51.51% of the funds (a total of 5,039,116 euro), GBYP deployed 85.50 % of the conventional tags (25,650) and 110.33 % of the electronic tags (331; 273 mini PATs, 50 internal archival tags and 8 acoustic tags); furthermore, the tagging design and protocols, the awareness and rewarding campaigns were included in the activity carried out so far, while they were not included in the initial activities. It is very clear that the general objectives sets for the tagging activities in these first Phases were largely accomplished so far, taking into account the proportion of the available budget.

[4] Additional elements will be provided by the GBYP biological and genetic sampling and analyses.

The final reports of all electronic tagging activities in Phase 6 are in the **Annex 1a (documents no. 41, 42, 45, 47** and **50)**. The overview of the ICCAT GBYP tagging activities in the Phase 6 was presented on the 2017 Bluefin Tuna Data Preparatory Meeting as SCRS/2017/042 (**Annex 1b, document no. 31**).

5.2 Tags and correlate equipment

At first, ICCAT GBYP acquired a considerable amount of tags during these first Phases of the programme, allowing both the tag delivery to all stakeholders who have a bluefin tagging activity (either opportunistic or institutional) and to the GBYP contractors. The details of the materials and tags acquired so far by ICCAT GBYP or donated by various institutions are on SCRS/2017/042 (**Annex 1b, document no. 31**).

5.3 Tagging activities

In the Phase 6, the ICCAT GBYP Steering Committee decided to proceed with the electronic tagging activities, keeping the conventional tagging only as a complimentary activity. It was decided to focus the attention for the first part of the tagging on the eastern Mediterranean Sea, where recent tagging activities were limited to the last GBYP ones in 2015, in the Moroccan traps, where all recent tagging activities showed variable behaviour of the bluefin tuna passing in this area and in the Sardinian area where electronic tagging was carried out in 2015 at the beginning of the spawning seasons.

For the first part of the tagging activity in 2016, a call for tenders was published in April and the contracts were awarded to a consortium led by COMBIOMA for tagging in Sardinian traps, a consortium led by INRH for tagging in Moroccan traps and to the Istanbul University which, in partnership with UNIMAR, carried out the tagging in the Levantine Sea. In the first part of the tagging activities, a total of 53 electronic pop up tags were implanted on adult bluefin tunas in these areas.

The second part of the tagging activities was intended to be carried out in the Strait of Messina (central Mediterranean Sea), where tagging activities on "resident tunas" have not yet been carried out, in the Portuguese traps, where bluefin tuna moving into the Atlantic after spawning can be tagged and the sea off Ireland, where some tagging was carried out in the past. After releasing the call for tenders two contract were provided, to UNIMAR for tagging in the Strait of Messina and to TUNIPEX for tagging in Portuguese trap, while the contract for tagging off Ireland was suspended by the Steering Committee after being released. 24 e-tags were implanted in Portugal and another 15 in the Strait of Messina. It is important to stress that 3 of the PSATs deployed in the Strait of Messina were kindly donated by the WWF and the tagging data results will be shared. Another 3 donated tags are to be deployed in the following phases.

The final reports of these activities are attached in **Annex 1a, document no. 41, 42, 45, 47 and 50.**

The preliminary results of the tagging activities in Phase 6 show the important number of premature detachments.

The reason for this probably lies in the high fishing pressure, the same problem that we faced in the Phase 5, as already discussed in the paper SCRS/2016/138 (**Annex 1b, document no. 5**). Additionally, this year the PSAT tags supplied by Wildlife Computers, which were used for the ICCAT GBYP tagging, were technically modified in terms of adding the automatic release device situated in the tag tether. As recognized by the manufacturer, a great deal of the premature detachments was due to the broken pin, which was more sensible than it should have been according to the technical specifications. As a matter of fact, out of 92 tags deployed in Phase, 25 detached because of the broken pin. The negotiation process with the producer has been initiated and the producer in August recalled and replaced the malfunctioning tags that hadn't been deployed yet and provided more robust ones. Additionally, the producer provided the guarantee that all tags already implanted, that have released before their scheduled pop-off date due to this technical failure mode, will be replaced free of charge, compensating the damages with a double replacement for each tag.

According to the results of the tags data processing, it seems that this year all tunas tagged in Morocco entered immediately into the Mediterranean Sea for spawning (**Figure 5**). This is different from the tagging results of previous years showing only a proportion of tagged tunas entering the Mediterranean, while the others stayed in the Atlantic Sea. The previous results are consistent with the results providing from the GBYP Biological Studies, showing each year different proportion of tunas in Morocco belonging to the eastern and western stock; therefore, we suspect that all tunas tagged in Morocco in Phase 6 should be EBFT.

Figure 5. Tracks of the electronic tags deployed in Morocco in 2016.

The tunas tagged in Portugal showed a different pattern, heading towards the North Atlantic feeding areas (**Figure 6**). These were expected results, having in mind that these tunas were tagged after the spawning season; it is important to notice that one of the bluefin tuna tagged in Portugal showed a different displacement from the others, moving toward the Azores.

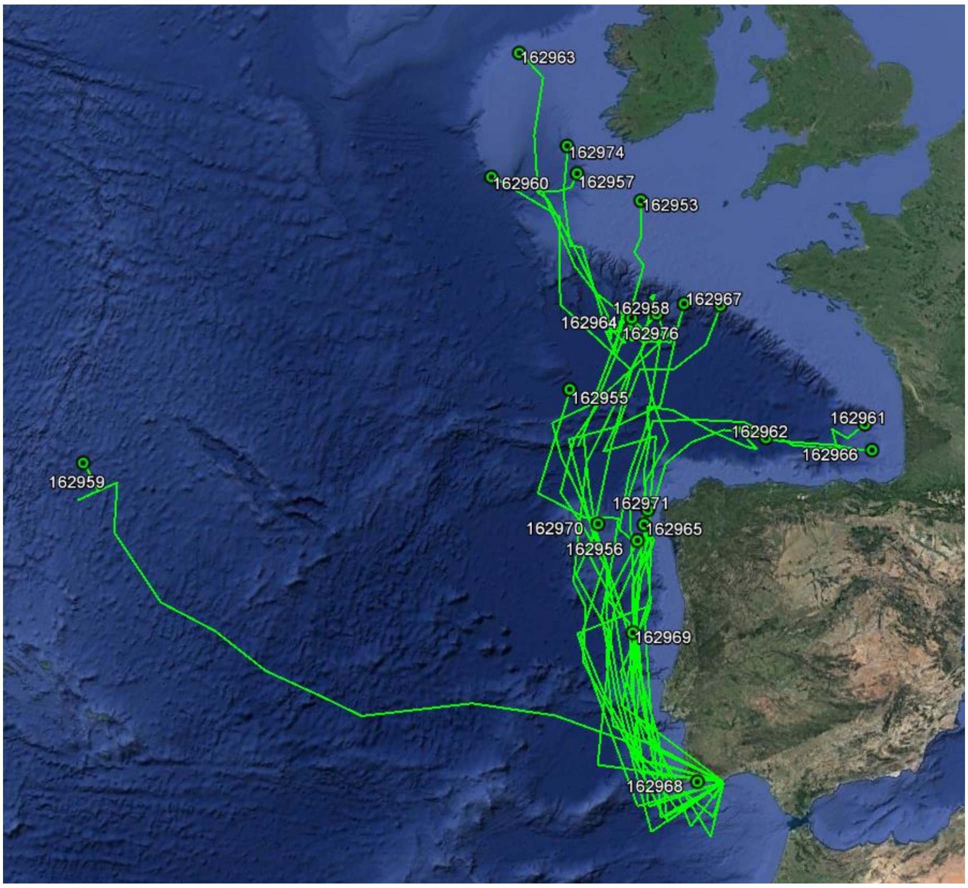


Figure 6. Tracks of the electronic tags deployed in Portugal in 2016.

Figure 7. Tracks of the electronic tags deployed in Sardinia in 2016.

The bluefin tunas tagged in Sardinia stayed in the western Mediterranean (**Figure 7**), which is a behaviour similar to what have been already observed in 2015, when none of the tunas tagged in Sardinia had left the Mediterranean Sea. Regarding the bluefin tunas tagged in the Levantine Sea, the observed behaviour is the same as the last year (**Figure 8**). Although the majority of tags detached in a short period of time which didn't provide us the chance to record the displacements of these tunas after spawning, it seems that the majority were heading west, and some tunas reached western Mediterranean areas before their tag popped off.

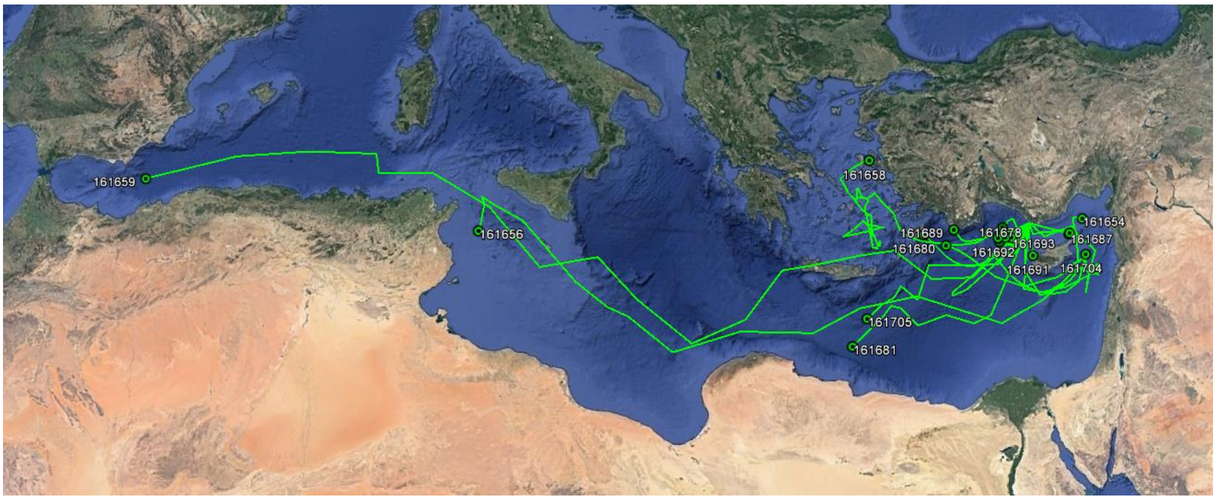


Figure 8. Tracks of the electronic tags deployed in the Levantine Sea in 2016.

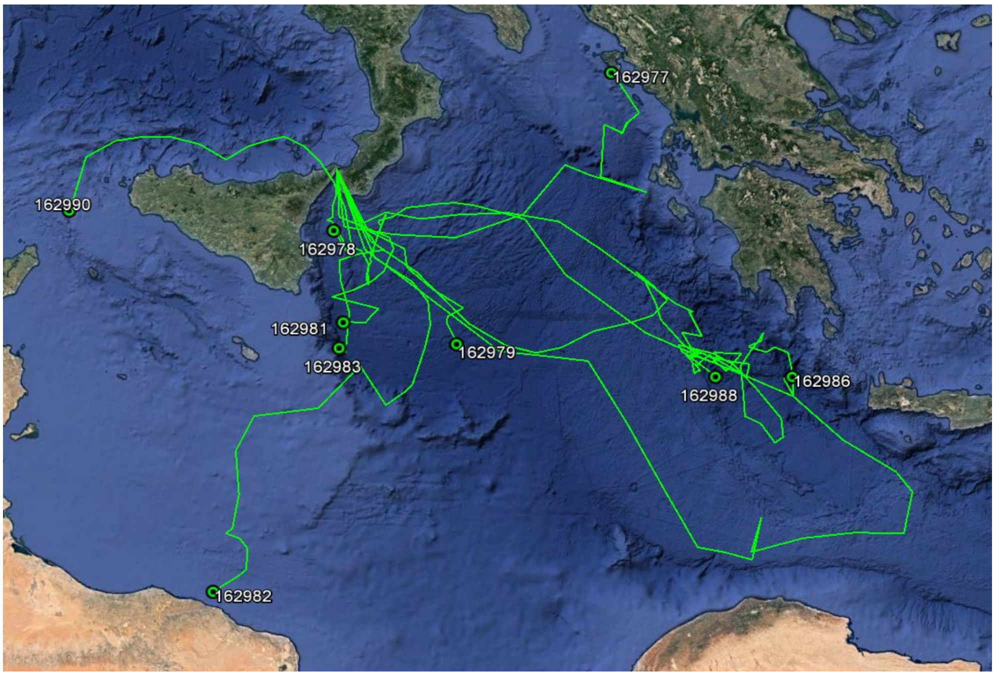


Figure 9. Tracks of the electronic tags deployed in the Strait of Messina in 2016.

The bluefin tunas tagged in the Strait of Messina mostly stayed in the area of Central Mediterranean (**Figure 9**). This was expected behaviour having in mind that these tunas were tagged after the spawning season and therefore included mainly or only Mediterranean "resident tunas", those overwintering in the Mediterranean Sea.

5.4 The analysis of the PSAT tags data

A summary of all ICCAT GBYP PSAT tags that were deployed between 2011 and 2015 (Phase 6 was not included) was provided by SCRS/2016/138 (**Annex 1b document no. 5**). The analysis was carried out in-home, by the GBYP team. Out of 193 tags implanted by the time the report was prepared, the full datasets were recovered from 173 tags. The longest received dataset was recovered from the tag which stayed 337 days attached to the fish. A brief discussion was provided on how the real tag dataset duration is in most cases shorter than the period between the deployments and the pop-up, because the tag detachment may happens few days before the tag starts transmitting to the satellite. It is very important that in all future PSAT tags data analysis this fact is taken into account in order to remove the data between the detachment and the pop off, for avoiding a bias in an integrated analysis. A brief analysis of the potential cause of the tag detachment was discussed in detail and the method was established for determining various possible causes, concentrating to the specific behavior of the tuna when they are caught by different fishing gear. The results indicated a huge number of detachments possibly due to the fishing activities (75%). For the first time, the detailed specifications for trying to attribute a premature detachment to a specific fishing gear type are now available and this new information was deeply appreciated by the SCRS BFT Intersessional meeting.

The analysis of tag reporting performance was also performed and it indicated a slight technological improvement over the time. Tag trajectories revealed many interesting moving patterns for bluefin tunas, some of which were previously unknown and present a great contribution of the GBYP programme to the science. The analysis of the time the bluefin tuna spends close to the surface in the Mediterranean was also performed and it was found that there is a significant difference in its behaviour during the spawning and non-spawning season (**Figure 10**). During spawning season (in the Mediterranean from May to August) bluefin tuna spend more time in the upper water column, which was expected result having in mind that spawning occurs at the surface.

All data sets from electronic tags deployed by the GBYP in all Phases were provided to Ph.D. Matt Lauretta (in charge of collecting and analysing all satellite tags data sets on behalf of the SCRS BFT Species Group) and to Tom Carruthers (the modelling expert in charge of developing the technical aspects on behalf of the ICCAT GBYP Core Modelling MSE Group).

It has to be noted that GBYP is only one of the entities providing PSAT data to the two experts. Although if recently there has been a great progress in a quantity of data these experts received, there are still some entities that didn't provide their electronic tags data. GBYP in the Phase 6 awarded a contract to Prof. Barbara Block, for recovering the data from Tag-A-Giant research programme of the Stanford University. The datasets of 392 electronic tags were provided in the framework of this contract and are now available to the two experts for modelling purposes.

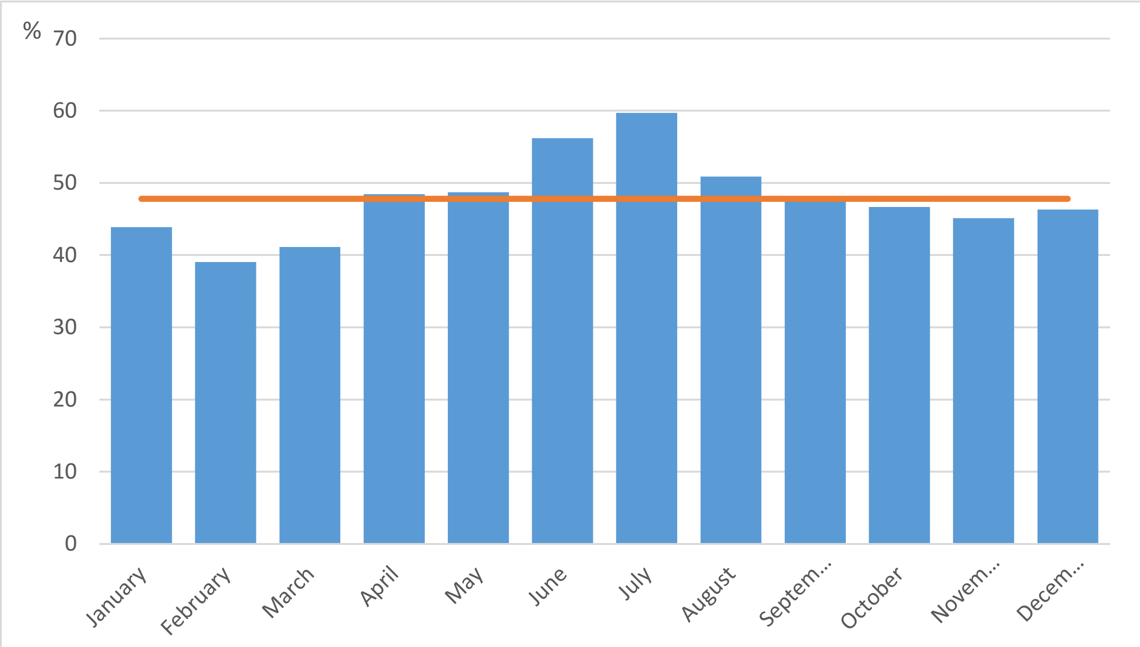


Figure 10. Mean percentage of time bluefin tuna spent on the surface (0-10 m) by months, according to the data provided by electronic pop up tags deployed by ICCAT GBYP (2011-2015). Orange line represents the mean percentage of time spent on the surface (1-10 m) throughout the year.

Following a specific recommendation of the GBYP Steering Committee, a contract was given to CLS for reprocessing of 107 tag datasets at the end of Phase 6. CLS is the company that processed all ICCAT GBYP electronic tag datasets so far, using the special algorithm developed by them for calculating the maximum probable geolocations out of raw data on light, depth and temperature. Since the beginning of the ICCAT GBYP tagging programme, CLS algorithm has been improved, therefore providing results in slightly different format. In order to have the all results in the same format and therefore comparable, a re-processing of older tags was carried out, by using the newest algorithm. The results are attached in **Annex 1a, Document no. 51**.

5.5 The analysis of displacements of tagged BFT

As concerns the displacement data provided by the conventional tags, the basic analysis for those fish that have both release and recovery position was carried out and the results are presented in the paper SCRS/2016/143 (**Annex 1b, document no. 10**). A set of maps was elaborated for better representing the current situation and for showing the various movements of the bluefin tunas using tag release/tag recovery data. As a matter of fact, over 5,962 fish having both data, 5,434 fish (equal to 91.14%) had position data that have been validated. For plotting the displacements data by decade, it was decided to use the recovery date as reference. The maps of bluefin tuna displacements using conventional tags deployed by ICCAT GBYP, as shown on **Figure 11**.

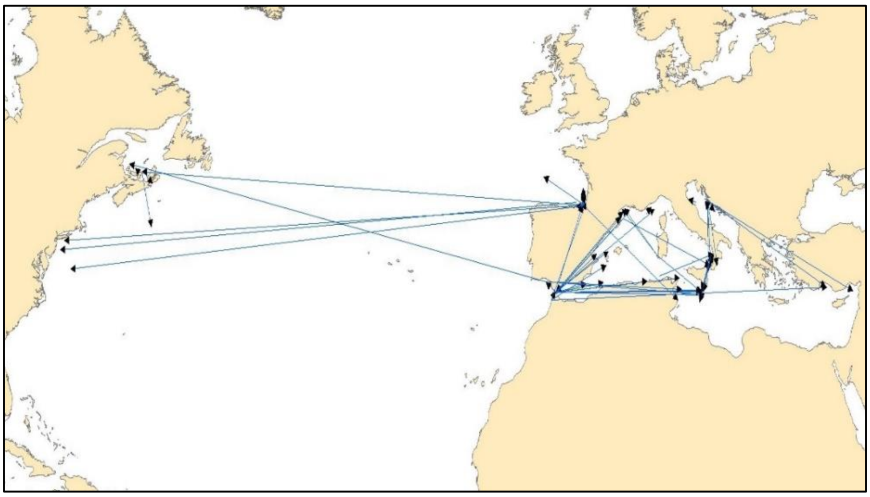


Figure 11. Bluefin tuna displacements for all individuals tagged and recovered under the GBYP (2011-2016) with geo-data validated.

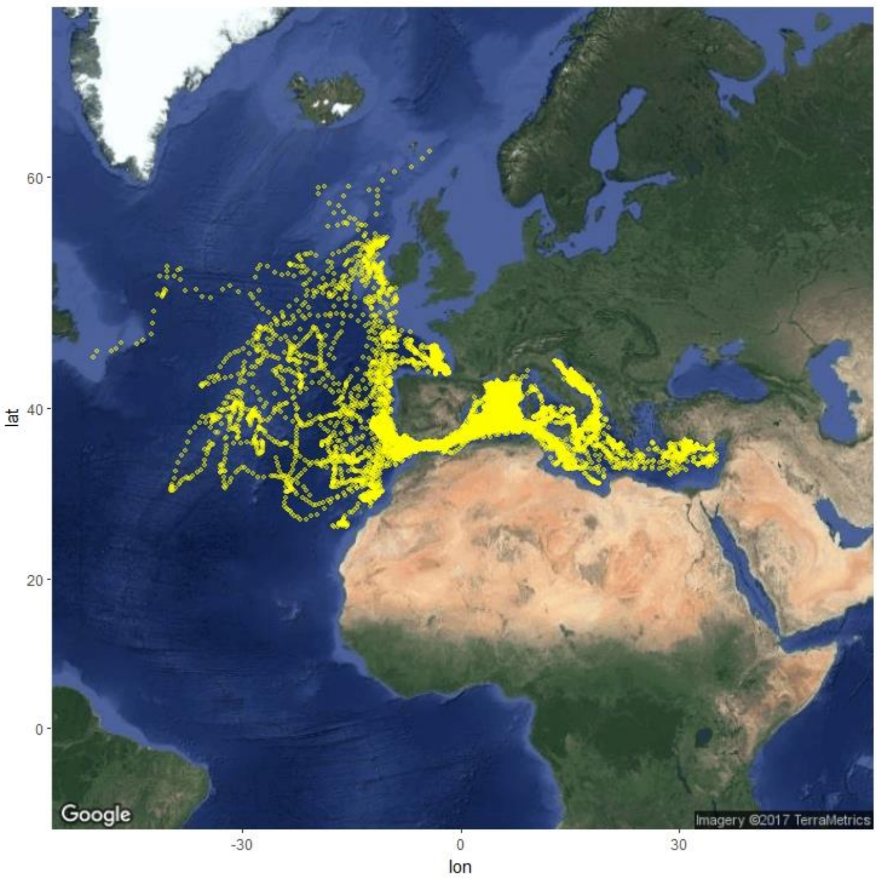


Figure 12: Daily geolocation estimates of 250 bluefin tunas tagged by ICCAT GBYP in the period between 2011 and 2016 pooled together

As concerns the electronic tags (minPATs) deployed within the framework of the GBYP in the period 2011-2016, a summary of all daily geolocation estimates are shown in the **Figure 12**. Tag trajectories revealed some very interesting bluefin tuna movements and migration paths. The basic analysis of the tags implanted up to Phase 5 has already been provided on the paper SCRS/2016/138 (**Annex 1b, document no. 5**), while the results of the electronic tagging carried out in Phase 6 will be integrated later, when all deployed tags will pop-off.

5.6 Tag awareness campaign

This activity is considered essential for improving the very 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. In total, more than 15,750 posters of various sizes (A1, A3 and A4) and more than 18,000 stickers were produced so far; two posters and all stickers were revised in 2014. All posters are also available on the ICCAT-GBYP web page http://www.iccat.int/GBYP/en/AwCamp.asp . A capillary distribution of the tag awareness material was carried out directly by GBYP, sending copies to all stakeholders such as: Government Agencies, scientific institutions, tuna scientists, tuna industries, fishers, sport fishery federations and associations, the RFMOs and RACs concerned; the coverage was complete in the ICCAT Convention area, including also non-ICCAT countries and entities fishing in the area. The map clearly shows the distribution effort (**Figure 13**). The ICCAT-GBYP web page has the full list of contacts http://www.iccat.int/GBYP/images/mapamunditicks.jpg .

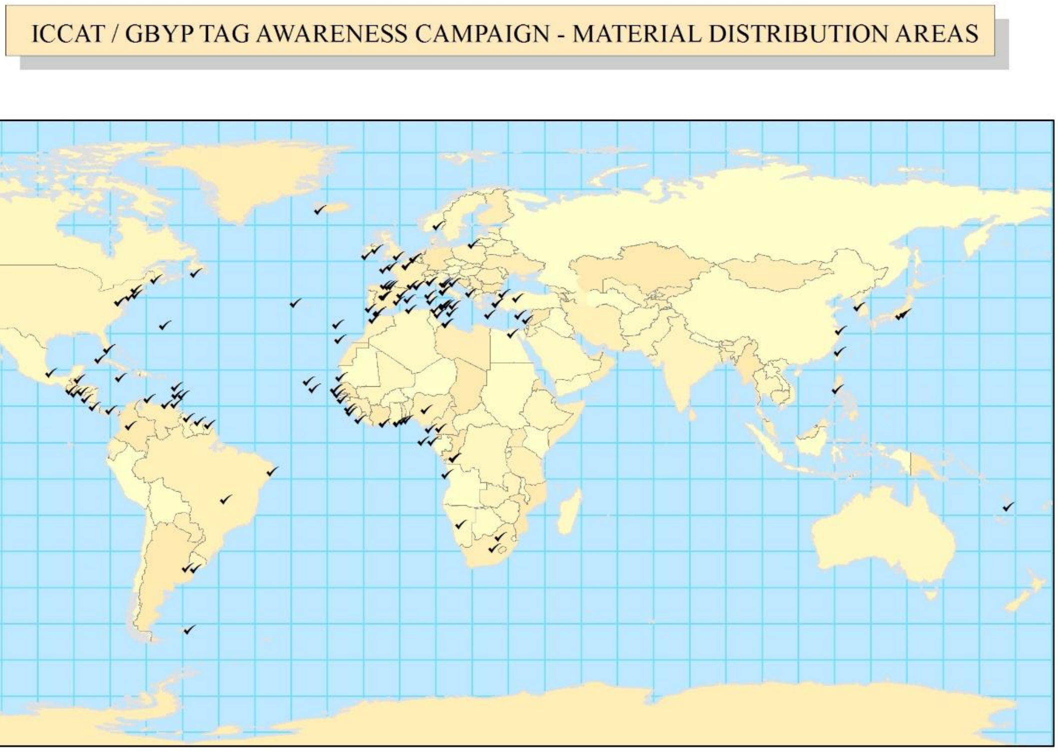


Figure 13. ICCAT GBYP Tag awareness campaign- material distribution locations

The GBYP staff actively participated every year (except in 2016 because it was not authorised) to the training of ICCAT ROPs, with a specific focus on tag awareness and tag recovery, but also for having reports of any natural tag in bluefin tuna harvested in farms.

Posters are now present in most of the ports where bluefin tuna are usually or potentially landed, in tuna farms, tuna traps, industries, sport fishers clubs, fishers associations, bars where fishers are usually going, local port authorities and on many fishing vessels. Some articles were also promoted and they have been published on newspapers and magazines.

In the Phase 6, a call for tenders was released for producing short videos and spots propaganda and awareness on ICCAT GBYP tagging activities, specially focusing on their contribution to the scientific knowledge, the sustainability of fisheries and the available rewards. The contract was awarded to the audio-visual producer company MALVALANDA from Spain, for developing a short 5 minutes documentary and a shorter 40 seconds video spot. The videos were translated in 8 languages. They were already presented at the SCRS meeting in September 2016. It is envisaged to develop the ICCAT GBYP bluefin tuna tagging visibility campaign and use these video materials for this purpose, by distributing them to main TV stations and other media in Mediterranean CPCs. All videos are uploaded to the YouTube as a preview (https://www.youtube.com/channel/UCK25VrRxTajo-7I0AQbNQxw) (**Annex A1, document no. 54**) and their download in the high quality is easily available on request. An ICCAT circular letter (391-2017) was sent to CPCs informing them about the purpose and significance of these videos and that the videos are easily accessible.

5.7 Tag reward policy

Following the recommendations made by SCRS and the GBYP Steering Committee, the ICCAT GBYP tag reward policy was considerably improved since the beginning, with the purpose of increasing the tag recovery rate which was extremely and unacceptably low. 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 considerably improving the tag reporting.

5.8 Tag recovery and tag reporting

This activity is the final result of the activities listed in previous points. For further improving the results, meetings with ICCAT ROPs were organised in earlier years, further informing them about the ICCAT GBYP tag recovery activity and asking them to pay the maximum attention to tags (and to natural marks) when observing harvesting in cages or any fishing activity at sea. Special information forms have been provided to ICCAT ROPs.

While examining the results of the ICCAT GBYP tag recovery/reporting activities, it is very important to consider that about 90% of the conventionally tagged fish in Phases 2-4 were juveniles (age 0-3); about 70% were surely immature fish (age 0-2) and then it is difficult for these fish to be caught by most of the fisheries, particularly taking into account the ICCAT minimum size regulation and the fact that the baitboat fishery in the Bay of Biscay in the last years was almost nil, because fishermen sold their quota to other fisheries. Furthermore, the institutional GBYP conventional tagging campaign was suspended in the Phase 5 and Phase 6.

Since the first year of the GBYP and up to 21 February 2017, there have been 565 tags recovered by GBYP. The GBYP recoveries are summarized as follow:

- 352 Conventional “Spaghetti” tags (62.3 % of the total)
- 169 Conventional “Double-barb” (two types) tags (29.9% of the total)
- 25 External Electronic “mini-PATs” tags (4.4 % of the total)
- 12 Internal Electronic “Archivals” tags (2.1 % of the total)
- 3 Acoustic tags (0.5% of the total)
- 4 Commercial “Trade” bluefin tuna tag (0.7% of the total)

The distribution of tag recovered by area and fishery[5] is showed on **Table 6** and **Table 7**.

Table 6. Geographical distribution of the areas where the tag recoveries occurred, in numbers and percent, by type of tag (up to February 21, 2017).

Fishing Area / Tags	Spaghetti Tags	Double BarbTags	External Elec. Tags	Internal Elec. Tags	Acoustic Tags	Commercial Tags	Grand Total	%
East Atl	58	32	11	1		1	103	18,23
Med	270	114	10	10	3		407	72,04
North Atl	14	6				2	22	3,89
West Atl	10	17		1		1	29	5,13
Unknown			4				4	0,71
Grand Total	352	169	25	12	3	4	565	100
%ge	62,3%	29,9%	4,4%	2,1%	0,5%	0,7%	100,0%	

The number of tags reported by two important commercial activities in the Eastern Atlantic and in the Mediterranean Sea (purse-seiners/cages and tuna traps) is surprisingly very low. The purse-seine fishery is historically the most productive in the last decades, reaching over 70% of the total catch in some years; since 1999, almost all purse-seine catches (and, in recent years, also most of the trap catches) are moved to cages and then to fattening farms and these activities are strictly monitored by ICCAT observers (ROPs). Consequently, the GBYP was supposed to have a high tag recovery and reporting rate from purse-seiners/farms, but the data are showing a different reality: the farms had recovered 89 tags, of various types (62 single-barb spaghetti, 18 double-barb spaghetti, 5 internal, 1 PSAT and 3 acoustic), while 22 were recovered from purse-seiners (14 single-barb spaghetti, 6 double-barb spaghetti, 1 PSAT and 1 internal). Even considering that most of the last conventional tagging activities were targeting juveniles, the recovery and reporting rate is unrealistically too low (15.75% of the total reported tags for the farms and 3.89% for the purse-seiners, which means 19.64% for the PS activities in total).

[5] For comparison purposes, but also because the data were not previously reported, we included in the table also the tags recovered by ICCAT between 2002 and 2009, before GBYP. These tags were only 7 (4 spaghetti, 1 double barb spaghetti and 2 internal archival).

The same conclusions can be stated for the traps, because they have reported only 9 tags to ICCAT within the period taken into account (4 single-barb spaghetti, 3 double-barb spaghetti, 2 internal archival). Even in this case, the recovery and reporting rate (1.59% of the total recovered tags) is unrealistically too low. A similar consideration is applicable even to the long-line fishery; including both the bluefin tuna targeted fishery and the many long-liners targeting other pelagic species having the bluefin tuna as a by-catch (52 tags in total, 34 single-barb spaghetti, 16 double-barb spaghetti and 2 internal, equal to 9.20% of the total). The possible reasons for the low reporting rates from all these relevant fisheries have been already discussed at the document SCRS/2013/177.

Table 7. Details of tag reported to ICCAT GBYP by fishery, in numbers and percent, up to February 21, 2017.

Fishery -Gear / Tags	Spaghetti Tags	Double BarbTags	External Elec. Tags	Internal Elec. Tags	Acoustic Tags	Commercial Tags	Grand Total	%
BB	163	79					242	42,83
FARM	62	18	1	5	3		89	15,75
HAND	21	12	1				34	6,02
LL	34	16		2			52	9,20
LLHB	2	2					4	0,71
NF			13			4	17	3,01
PS	14	6	1	1			22	3,89
RR	14	25		2			41	7,26
SPOR	11	1					12	2,12
TN	1	1					2	0,35
TRAP	4	3		2			9	1,59
TROL	12	4					16	2,83
UNCL	14	2	9				25	4,42
Grand Total	352	169	25	12	3	4	565	100

Table 8. BFT tags reported by year to GBYP (yellow shading means tags reported to ICCAT prior to GBYP).

Recovery Year / Tags	Spaghetti Tags	Double BarbTags	External Elec. Tags	Internal Elec. Tags	Acoustic Tags	Commercial Tags	Grand Total	%
2002	1	1		1			3	
2006	1			1			2	
2008	1						1	
2009	1						1	
TOT 2002-2009	4	1	0	2	0	0	7	
2010	3						3	0,53
2011	8		1				9	1,59
2012	36	7	6	1		1	51	9,03
2013	60	28	9	2		1	100	17,70
2014	72	30	1	3		2	108	19,12
2015	68	46	3	3	1		121	21,42
2016	93	54	3	3	1		154	27,26
2017	12	4			1		17	
Undefined (2012 or 2013)			2				2	0,35
Grand Total	352	169	25	12	3	4	565	100

The important tag reporting improvement registered after the beginning of the tagging and tag awareness activities by ICCAT GBYP is impressive (**Table 8** and **Figure 14**): the average ICCAT recovery for the period 2002-2009 was only 0.88 tags per year, while during GBYP tag recovery activities the average was 80.7 tags per year. 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 2016, a total of 154 tags were recovered, in spite of the fact that conventional tagging was almost suspended from the 2015 and that in 2014, due to recommendation of the Steering Committee, ant the conventional tagging was almost exclusively limited to the complimentary taggig. In the year 2017, up to the February 21, 17 tags have been recovered. We have to note that, for the first time in ICCAT bluefin tuna tagging activities, the number of tags recovered and reported from the Mediterranean Sea is higher than any other area. Considering that reported tags from the Mediterranean were almost nil before GBYP, this is the clear evidence that GBYP tag awareness campaign is producing positive effects.

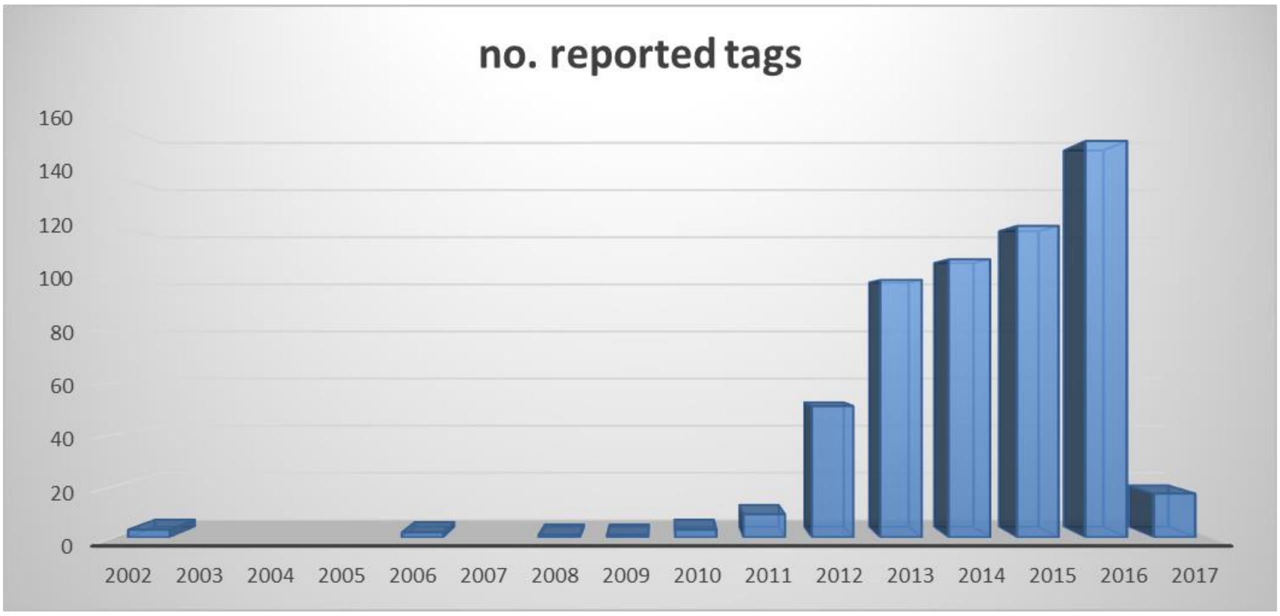


Figure 14. Number of bluefin tuna tags reported to ICCAT by year, up to February 21, 2017.

It is extremely difficult and almost impossible at the moment to define a recovery rate for GBYP conventional tagging activities, taking into account that most of the conventionally tagged tunas were juveniles and they will be possibly available in most of the fisheries within the ICCAT Convention area only in future years. Whenever we consider, as a preliminary exercise, the number of tags recovered so far in comparison with the number of GBYP tags deployed, the provisional recovery rate is 2.17 %, but this rate is clearly negatively biased by the juvenile ages of about 90% of the tagged fish. At the same time, it is impossible assessing the recovery rate of tags which were not deployed by ICCAT GBYP, because ICCAT does not have the insight in the total number of implanted tags by each tagging entity in the ICCAT area.

Interesting information is slowly coming from the double tagged tunas (**Table 9**): up to February 21, 2017, tags were recovered from 275 double tagged fish and both tags have been recovered from 106 fish (67.72% of the double tagged fish recoveries). 27 fish had only the billfish (double-barb) tag on, while other 36 fish had only the single barb spaghetti on. According to these first data, it seems that both types of tags (single barb and double barb) are more or less equally resistant, with the slight better resilience for the single barb. The tag recovery rate for all double tagged fish by GBYP is currently 2.14%.

Table 9. BFT tag recoveries from double tagged fish by type (up to 21 February 2017).

Release	Spaghetti tag only	Double Barb Tag only	Both	TOTAL FISH	TOTAL TAGS
2011	1	5	5	11	16
2012	10	9	41	60	101
2013	24	12	59	95	154
2016	1	1	1	3	4
Total	36	27	106	169	**275**
%	21,30	15,98	62,72	100	

RcCode: 2conv			**both recovered**				
	Year of Recovery						
Year of Release	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**TOTAL FISH D/T**
2011	1	3	2	0	0		6
2012	5	15	10	3	6	1	40
2013		6	15	17	19	2	59
2014				1	0		1
2016					1		1
TOTAL	6	24	27	21	26	3	107
%	5,61	22,43	25,23	19,63	24,30	2,80	100,00

Reiterating what it was said in the first part of the ICCAT GBYP, the extreme importance of having all tag release data related to all tagging activities carried out on bluefin tuna (but also on all other species under the management of ICCAT) concentrated in the ICCAT tag data base should be mandatory. This is essential because recoveries can be logically reported to ICCAT at any time and it is not always easy, rather time/effort consuming, finding the entity which implanted the tags if data are not properly stored. As usual, the GBYP staff had experienced a lot of difficulties in recovering the tag release data in several cases, with an important additional workload. At the moment this tag release communication is not mandatory, but it should be, because it has a general interest, including for the various entities and institutions carrying out this activity.

5.9 Close-kin tagging

As a possible alternative to the conventional tagging or as additional tagging approach, the ICCAT GBYP Steering Committee recommended to explore and evaluate the close-kin genetic tagging (Close Kin Mark Recapture, CKMR). It is a new approach to estimate the SSB abundance and other important population parameters that is currently applied for some fish species (including sharks), some marine mammals species, for the southern Bluefin tuna and that will be possibly applied also for the Pacific Bluefin tuna. CKMR uses information on the frequency and distribution in space and time of closely genetically related individuals in samples of tissue from live or dead animals.

According to CSIRO, the initial application of CKMR model to the southern Bluefin tuna (SBT) was relatively simple, given the fact that it is a single population with only one known spawning ground and one main area for the distribution of juveniles. On the contrary, possible application of the method to the Atlantic bluefin tuna is rather challenging, given the variable rate of mixing of the east and west population throughout the Atlantic Ocean, a series of uncertainties regarding bluefin tuna biological characteristics, possible additional spawning areas outside the Mediterranean Sea and the Gulf of Mexico, and a complex logistic/operational environment. One of the main assumptions for the application of this method is to have enough number of high quality samples of both spawning adults and juveniles, obtained from strategically distributed sampling locations and surely from the main spawning areas.

For the purpose of obtaining the advice on close-kin tagging and a feasibility study, a call for tenders was released in the last part of the Phase 5, and the contract was awarded to The Commonwealth Scientific and Industrial Research Organisation (CSIRO) from Australia. Due to the important delay linked to time constraints for the conclusion of Phase 5, the original terms of reference were split in two parts by the Steering Committee: a first part of the feasibility study to be done during Phase 5 and, depending to the availability of funds, the possible follow up which would be done in Phase 6.

Given the fact that CSIRO provided its report with considerable delay and with some problems in the contents, the Steering Committee decided to have a refined and revised report and to ask CSIRO to provide the necessary elements for programming a workshop for genetic analyses needed for the CKMR approach in Phase 6, before going on with the workshop and the second part of the CKMR feasibility study in Phase 7. The purpose of the workshop is interchange of the knowledge and technics on BFT genetics, especially having in mind recent discoveries in the field which might somehow reduce the costs of samples analyses. It is planned that it will be attended by the experts in genetics who have previous experience in analysing BFT samples within the GBYP and the ones that have experience on analysing genetic for the purpose of southern bluefin CKMR.

The updated and revised report provided by CSIRO (**Annex 1a. Document no. 52**) takes into consideration the comments provided by the ICCAT Secretariat and by the experts from BFT Working Group. The short technical report provided more detailed consideration on the genetics requirements for design and implementation of CKMR for bluefin tuna (**Annex 1a. Document no. 53**).

The report made by CSIRO considers that CKMR should be potentially feasible for EBFT, assuming it is possible to: (i) increase the annual sample size of tissue, otolith and length samples obtained from within Mediterranean and eastern/central Atlantic sampling programs; (ii) distinguish between individuals of eastern and western origin with a high probability; and (iii) implement high quality sample, processing and data management programs to minimise the likelihood of genotyping errors.

Assuming a primary design criterion of a CV of around 15% on the estimated 2014 spawning biomass, it appears that the desired CV might be obtainable for total sample sizes (i.e. adult and juveniles) in the order of ~30,000-40,000 individuals (from a maximum CV 0.29 for 4,000 samples per year for 3 years to a minimum CV 0.05 for 20,000 samples per year for 5 years). The total number of samples required should not depend too much on the actual number of spawning[6] and juvenile grounds, but will depend somewhat on the duration of the study (considering 3, 4, and 5 year design) and other design details such e.g. what size of adults to concentrate on genotyping. More importantly, though, the actual number of samples required may well turn out to be considerably different, because the true stock size and other true biological parameters (including the nature of any population structure) may themselves well be quite different from (i) the current stock assessment results on which the calculations were based on, and from (ii) other assumptions (e.g. about mixing proportions) that will need to be made in order to explore possible designs. Sample sizes can be adjusted as the study goes on and knowledge accumulates, especially if extra samples are collected (cheap) but not genotyped (less cheap) in the first pass, but are available subsequently for genotyping if sample sizes need to be increased (in order to find enough kin-pairs to make a reliable estimate).

Given that it was not possible for the contractor to provide a realistic costing for the CKMR study in this primary stage, the GBYP Steering Committee decided to start collecting the necessary samples as much as possible for practically testing the feasibility and the real costs for carrying out a CKMR study for EBFT already during Phase 6. An enhanced sampling was done within the Biological studies for both juveniles and adults in major spawning areas, also for testing the problems and not only the real costs. As a first result, sampling for adult spawners in the spawning areas resulted feasible in the Balearic area, in the southern Tyrrhenian Sea and in the central-southern Mediterranean, but with much higher costs compared to the first part of the CKMR feasibility study, while sampling of adults in the Levantine Sea was only partly feasible, due to the difficulties encountered in the Turkish area by the local scientists. For the YOY, in 2016 there was a peculiar situation in the Mediterranean Sea, which prevented a full sampling in most of the areas.

The report concerning the preparation of the workshop for CKMR genetic possibly better describes the current problems of this technique when it is applied to a species having a so large distribution area.

When the report for the first part of the feasibility study was provided by CSIRO along with the report for programming the workshop on CKMR genetics, the CSIRO also stated its unavailability for carrying out the second part of the feasibility study in Phase 7 (as it was planned), due to a considerable workload but also to the need to further check the CKMR technique applied to tunas. At the same time, due to the same reasons, they proposed to move at least to Phase 8 both the second part of the feasibility study and the workshop.

6. Biological Studies

The initial, short-term ICCAT GBYP objective approved by the Commission in 2008 was to collect samples from 12,000 fish (including western Atlantic and the Japanese catches and markets) and carry out ageing and genetic

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[6] Always considering that the spawning ground for the EBFT was the Mediterranean Sea in the study, while everything will change if additional spawning areas will be detected.

studies, and micro-constituent analyses in three years in the eastern Atlantic and Mediterranean, with a total budget of 4,350,000 Euros. So far, with only about 60% of funding (2,612,054 euro[7]), the ICCAT GBYP collected samples from 9183 fish up to Phase 5, while additional 3551 fish were sampled in Phase 6, bringing the total to 12,734 fish, equal to 106.1% of the initial target (12,000 fish); furthermore the GBYP carried out aging, aging calibration, genetic and micro-constituent analyses; furthermore, the sampling design and protocols, and the otolith shape analyses were included in the activity carried out so far, even if they were not included in the initial plan. It is very clear that the general objectives sets for the biological studies in these first Phases were largely accomplished so far, taking into account the proportion of the available budget.

The GBYP biological sampling design was the one provided by the Institut National de Recherche Haulieutique (INRH - Morocco) on March 2011. The final approved version is available on the ICCAT-GBYP web site (http://www.iccat.int/GBYP/Documents/BIOLOGICAL%20STUDIES/PHASE%202/Rapport%20final%20design%20echantillonnage%20biologique%20ICCAT-GBYP.pdf).

All the activities carried out in previous Phases and the first part of Phase 6 concerning the biological sampling and analyses have already been presented to SCRS and the Commission in 2016 (SCRS/2016/193 in **Annex 1b document no. 17**), while the activities carried out in the second part of Phase 6 will be presented at the SCRS meetings in 2017.

6.1 Objectives

The main objective of this task was to improve understanding of key biological and ecological processes through broad scale biological sampling of live fish to be tagged and dead fish landed (e.g. gonads, muscles, otoliths, spines, etc.), histological analyses to determine bluefin tuna reproductive state and potential, and biological and genetics analyses to investigate mixing and population structure, namely to define the population structure of Atlantic bluefin tuna (*Thunnus thynnus*), with a particular attention to the age structure and the probable sub-populations identification.

6.2 Activities

The activities in previous GBYP Phases have been clearly able to accomplish their objectives. Of course, the activities in following Phases of GBYP are set for completing and improving the preliminary results and for better defining some issues, such as mixing between the two current stocks and the sub-population hypothesis, which may require several years of data and many analyses, depending on the available budget.

Following the recommendations of the Steering Committee and the SCRS, the GBYP plan for Phase 6, biological studies were planned mainly as the continuation of the activities already started in earlier phases. Sampling was extended to areas and fisheries not covered or poorly covered in previous Phases, according to the ICCAT GBYP

[7] The amount is very close to the final one, but few contracts are still to be invoiced and therefore is not the final figure.

sampling design. A particular attention was devoted to the collection of otoliths and to ageing studies with the objective of developing an updated ALK and otolith collection was made mandatory in all contracts. Additionally, the special effort was put into sampling of adult BFT in farms, because they were underrepresented in the previous Phases and a larger number of adult tuna is needed for the purpose of not only developing the annual age-length key, but also for assessing the feasibility of the close kin genetic tagging.

Regarding the biological analyses of the samples, the activities were aimed at continuation of the studies already initiated in the previous phases, but with the additional task to compare, for the first time, single nucleotide polymorphisms (SNPs) analyses and microsatellites analyses, using the same samples. At the same time, funds were devoted for carrying out a larger number of analyses and use most of the samples already collected in previous Phases. According to the decision of the Steering Committee, a special effort was put into the attempt to age the otoliths that have been collected during various phases of the Programme, but haven't been red nor aged so far.

In addition to these activities, the Steering Committee recommended to initiate an improved sampling activity of adult spawners fished in the four main spawning grounds in the Mediterranean Sea, with a double objective: a) improving in a considerable manner the otoliths and tissues samples and b) practically test bot the feasibility and the real costs in order to have more parameters for the second part of the feasibility study for CKMR. After preliminary contacts with all tuna farms, another invitation for sampling was released to the entities managing bluefin tuna farms in Spain, Malta and Turkey, for sampling adult bluefin tuna in the major spawning areas within the Mediterranean Sea. After receiving the proposals, three contracts were released. One contract was signed with Balfego & Balfego (EU-SP) for sampling 150 specimens from Balearic Sea, other contract was signed with the consortium headed by Taxon Estudios Ambientales (EU-SP) for sampling 170 specimens from Balearic Sea and the third one with the consortium headed by AquaBioTech (EU-ML) for sampling 300 individuals from the southern Tyrrhenian Sea and 300 from the central/southern Mediterranean Sea. There was no proposal received from the Turkish farms or even from the Turkish Government and therefore the sampling of adults from the Levantine Sea was intended to be accomplished through the regular sampling performed yearly by a Consortium carrying out Biological Studies. The final reports of these activities are attached in **Annex 1a document no. 18, 22 and 26**.

Following the release of the call for tender for biological studies, there were two bids received: one for performing both sampling and analyses and the other for a limited sampling only. A contract for biological studies in Phase 6 was again awarded to the Consortium headed by AZTI (SP), having this year 14 partners and 6 subcontractors, belonging to 11 different countries, for carrying out biological sampling and analyses. The final report of biological studies is attached in **Annex 1a document no. 28.**

Following a specific recommendation of the GBYP Steering Committee, a separate call for tenders was released for reading and aging of 2000 otoliths already collected in Phase 6. Besides several preliminary contacts with various laboratories, no bids have been received and therefore this activity was suspended.

Pursuant to the recommendation of the Steering Committee and the ICCAT SCRS in 2015, GBYP in the Phase 6 organized a dedicated Workshop on larval studies and surveys. The workshop was held in ICCAT headquarters in Madrid, on 12-14 September 2016 and was attended by around 20 eminent scientists in bluefin tuna larval biology from EU, USA and Japan. The workshop was considered quite successful and very useful even by the SCRS BFT Species Group. The report was presented to the SCRS (**Annex 1a, document no. 29** and **Annex 1b, document no. 20**).

6.3. Sampling

A total of 3588 bluefin tuna individuals have been sampled in Phase 6. From these, 1721 individuals were sampled under the additional contracts for sampling adults on farms, while 1867 individuals were collected by the Consortium. All the data on samples collected this year have already been merged with the general samples database and stored in tissue bank. **Table 10** shows the number of bluefin tuna sampled in each strata (area/size class combination).

Table 10. Number of bluefin tuna sampled in Phase 6 by area and size class. Empty cells indicate that no sampling was planned in that stratum. Green cells indicate strata where no sampling was planned, but some sampling was finally accomplished

		Age 0	Juveniles	Medium	Large	Total		
		<3 kg	3-25 kg	25-100 kg	>100 kg		Target	%
Eastern Mediterranean	Levantine Sea	36		95	14	145	350	41%
Central Mediterranean	East Sicily and Ionian	0		50	50	100	150	67%
	Adriatic Sea		50			50	50	100%
	Malta	0			345	345	450	77%
	Gulf of Gabes				229	229	0	>100%
Western Mediterranean	Balearic	218			546	764	425	180%
	Southern Spain	72				72	0	>100%
	Ligurian	20				20	50	40%
	Sardinia			6	21	27	50	54%
	Tyrrhenian Sea	113	19	108	499	739	600	123%
North Sea	Norway				200	200	0	>100%
East Atlantic-West African coast	Morocco				50	50	50	100%
	Madeira, Canary Islands	6			50	56	100	56%
Northeast Atlantic	Portugal			3	52	55	50	110%
	UK, Ireland				2	2	0	>100%
Central North Atlantic	Central and North Atlantic			16	668	684	50	1368%
North-Western Atlantic	Canada (Gulf Saint Lawrence)				50	50	0	>100%
	TOTAL	465	69	278	2776	3588	2375	151%

The original plan, according to the contract, was to acquire samples from 2375 individuals (1375 individuals by the Consortium members and 1000 individuals by the tagging teams and other contracts addressing specific sampling in tuna farms). Thus the overall current sampling status represents 151% of the target in terms of total number of individuals. By size class, the objectives for juvenile, medium and large fish were accomplished (>100%, >100% and 191% of the target respectively), but the final sampling for age 0 remains only at 50% with respect to the original target. It is necessary to note that no sampling for juveniles and medium size fish was planned, but some 11/101 individuals have been finally sampled in the Levantine Sea, East of Sicily and Ionian Sea, Sardinia, Tyrrhenian, Portugal and the Central Atlantic. With respect to adults, the overall target has been exceeded. Although sampling in the Levantine Sea and Sardinia were below the target, this was compensated by other areas where the target was exceeded (Malta, Balearics, Tyrrhenian, Portugal and the Central Atlantic), as well as areas where no sampling of adults was originally planned but some samples were finally obtained (East Sicily and Ionian Sea, Gulf of Gabes, Norway and Canada).

In the Eastern Mediterranean, sampling was below original plan for several reasons. The lower than expected number of YOY in the Levantine Sea this year was due to, among other possible reasons, the bad weather conditions and the prevailing disputes in Siria that did not allow normal fishing operations of small boats close to the border. Sampling of adults was far below the target this year as well, due to the internal problems in access to the farm. As for the Central Mediterranean, although the sampling target was reached, it was not possible to collect any YOY sample from Malta, due to the delay in issuing the national permit and bad weather conditions. Sampling in Western Mediterranean worked particularly well this year. Although the total number of samples was far above the target, the collection of the target number of YOY samples was not accomplished in this area. Sampling in the Atlantic went quite well and large and medium size bluefin tuna samples were obtained from Morocco, Portugal, Norway and Canary Islands. The YOY sampling in Canary Islands also encountered problems this year.

This year disappearance of YOY bluefin tuna from the coastal areas where they usually are distributed from late summer to autumn was confirmed by various scientists and fishermen. The possible reasons for this phenomenon are specific oceanographic and climatological conditions in 2016, as presented in the scientific paper SCRS/2017/040 (**Annex 1b document no. 29**) and SCRS/2017/041 (**Annex 1b document no. 30**).

6.4. Analyses

The analyses of the samples collected in Phase 6 and in previous Phases were done within the contract for the Biological studies issued to the Consortium headed by AZTI. The mayor part of the activities done in Phase 6 was follow up of the work already initiated earlier in the GBYP. The efforts were focused onto obtaining data on the stock of origin, which is particularly important for the stock assessment and MSE development.

6.4.1 Otolith chemistry

Otoliths of Atlantic bluefin tuna have proven to be highly effective tools to study the population structure and migratory pathways. Over fish’s life, otoliths grow by accumulating new material in concentric layers around the central nucleus. Examining the chemical composition of different portions of otolith informs about where fish have been at various life-stages. During Phase 6, otolith chemistry was used to answer different questions related with the ecology and stock structure of Atlantic bluefin tuna.

6.4.1.1. Determining nursery origin of bluefin tuna captured in potential mixing zones

The results from previous phases suggest that western origin contributions were negligible in the Mediterranean

Sea, Bay of Biscay and Strait of Gibraltar, but mixing rates could be important in the central North Atlantic, Canary Islands and the western coast of Morocco. In order to assess the spatial and temporal variability of mixing proportions, otoliths collected in areas with potential western contribution were analysed for stable carbon and oxygen isotopes ($\delta^{13}C$ and $\delta^{18}O$).

Stable isotopes were measured in the otolith cores of bluefin tuna from four locations in the Atlantic Ocean: 1) central North Atlantic Ocean (west of 45ºW), 2) central North Atlantic Ocean (east of 45ºW), 3) Atlantic coast of Morocco and 4) Canary Islands. **Table 11** summarises the attained results by region and sampling year in Phase 6.

Table 11. Maximum likehood predictions of the origin of bluefin tuna analysed in Phase 6. Estimates are given as percentages and mixed-stock analysis (HISEA program) was run under bootstrap mode with 1000 runs to obtain standard deviations around the estimated percentages

			Predicted Origin based on MLE			
Region	Year	N	FL (cm)	% East	% West	% SD
Central N. Atlantic (west of 45ºW)	2014	16	125-275	77.6	22.4	± 19.3
Central N. Atlantic (east of 45ºW)	2014	13	148-267	96.8	3.2	± 7.5
Morocco	2015	50	194-259	84.3	16.7	± 9.9
Canary Islands	2015	23	216-251	86.3	13.7	± 14.3
Canary Islands	2016	44	206-260	80.6	19.4	± 10.3

The results from Phase 6 (**Figure 15**), compared to the results obtained in the previous phases of the project, indicate that mixing rates between east and west originated fish show important interannual variability in all observed areas, further confirming the previous results. This information is extremely useful for better calibrating the mixing in the OM and the MSE.

The presence of no-eastern origin and no-western origin Bluefin tunas in the samples (or, as usually defined, "unassigned samples") is a part of the results which needs further studies and efforts, because they can potentially indicate fish born in areas outside the two main spawning grounds (GOM and MED), or other problems or simple uncertainties.

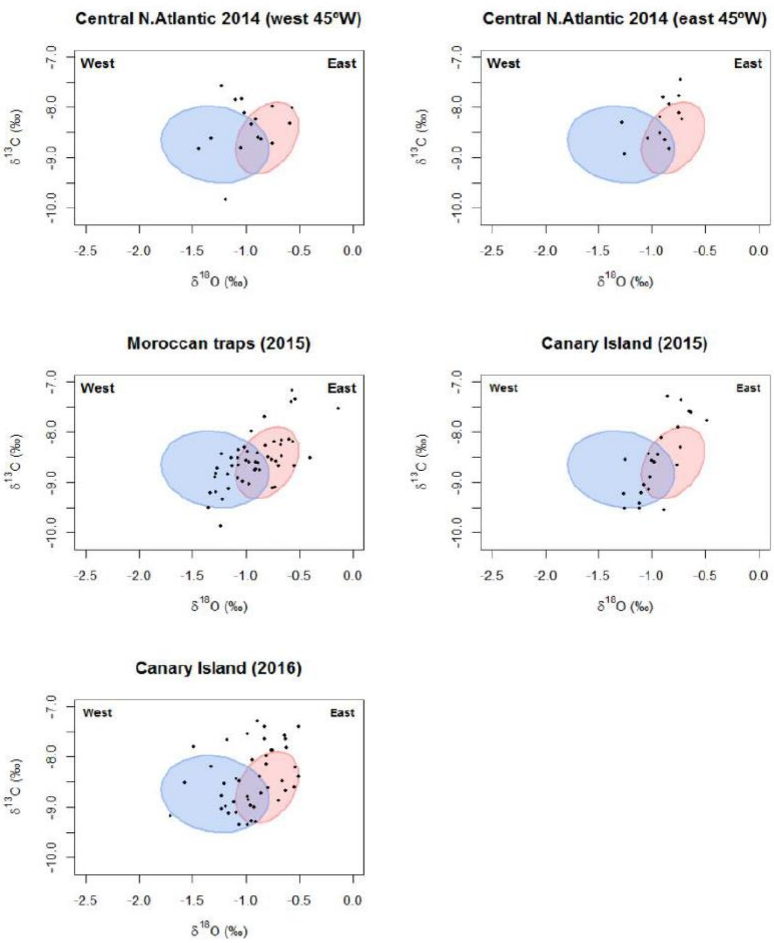


Figure 15. Confidence ellipses (1SD or cca. 68% of sample) for otolith $\delta^{13}C$ and $\delta^{18}O$ values of yearling bluefin tuna from the east (red) and west (blue) along with the isotopic values (black dots) for otolith cores of bluefin tuna collected from central North Atlantic (west of 45ºW), central North Atlantic (east of 45ºW), Moroccan traps and Canary Islands.

6.4.1.2. Individual origin assignment

During Phase 6, individual classification techniques were applied to isotope $\delta^{13}C$ and $\delta^{18}O$ values to predict the origin (Gulf of Mexico or the Mediterranean Sea) of 125 bluefin tuna at individual scale. For this purposes were used the samples already analysed in Task 1 (Determining nursery origin of bluefin tuna captured in potential mixing zones) – those from central North Atlantic Ocean (west of 45ºW), central North Atlantic Ocean (east of 45ºW), Atlantic coast of Morocco and Canary Islands.

Isotope $\delta^{13}C$ and $\delta^{18}O$ values of bluefin tuna otoliths were statistically analyzed and individuals were assigned to source populations with associated levels of probability. Among the classification methods tested with the baseline dataset, it has been shown that Quadratic Discriminant Function Analysis (QDFA) performs the best attaining the highest classification accuracy. Thus, QDFA was used to provide posterior probabilities for each pair of $\delta^{13}C$ and $\delta^{18}O$ values.

Individual origin assignments based on QDFA suggest that population mixing occurs in all studied regions at variable rates. Overall, mixing proportions using QDFA yield higher western contributions than MLE with proportions from QDFA often varying by at least 10% from estimates generated with the MLE approach (**Table 12**). However, considering the confidence intervals around those averages (i.e. mean+-2*s.d), the results are generally concordant.

Table 12. Quadratic Discriminant Function Analyses predictions of the origin of bluefin tuna analyzed in the Phase 6. Estimates are given as percentages and individual origin assignments were grouped by region and years.

	Predicted Origin based on QDFA			
Region	Year	N	% East	% West
Central N. Atlantic (west of 45°W)	2014	16	62.5	37.5
Central N. Atlantic (east of 45°W)	2014	13	84.6	15.4
Morocco	2015	50	70	30
Canary Islands	2015	23	73.9	26.1
Canary Islands	2016	44	72.7	27.3

6.4.1.3. Discrimination of nursery areas within the Mediterranean Sea by trace element and stable isotope composition in young-of-the-year bluefin tuna and origin assignation of individuals from Bay of Biscay

The results from previous phases suggested that trace element composition might allow discriminating the Atlantic bluefin tuna from different spawning areas of the Mediterranean Sea. In 2011, YOY signatures were distinct among eastern and western nurseries within the Mediterranean, allowing discrimination of the two major Mediterranean basins.

Due to significant interannual variation in the chemical signatures in the Mediterranean Sea, building a multiyear baseline for elemental signature is necessary when using trace element chemistry for classification of several year-classes. During Phase 6, stable isotope (δ13C and δ18O) and trace element analyses have been carried out on young-of-the-year (YOY) fish captured in the Balearic Sea, southern Tyrrhenian Sea, east of Sicily and Levantine Sea during 2013. Additionally, existing baseline was used to assign origin of 60 juvenile individuals of the 2011 cohort caught in the Bay of Biscay, for which otoliths were available. The results provide a first insight on which Mediterranean spawning area contributes most to this important feeding area of the northeast Atlantic in the studied years.

Ten isotopes (Li7, Mg24, Ca43, Mn55, Fe56, Co59, Ni60, Cu63, Zn66, Sr88 and Ba138) were measured in each otolith by the LA-ICPMS system. Once trace element analyses were completed, stable isotope analyses were performed on the same otolith. Multivariate statistics were used to determine the "within Mediterranean" nursery origin of bluefin tuna captured in the Bay of Biscay. HISEA software (Millar *et al*., 1990) was used under bootstrap mode with 1000 runs to generate maximum likelihood estimates of mixed-stock proportions in the Bay of Biscay.

The results (**Table 13**) suggest that the majority of bluefin tuna captured in the Bay of Biscay were originated in the central or Western Mediterranean Sea. Nevertheless, this hypothesis is based on a very limited number of analyses, and it is likely that the total number of contributing sources is not included in the baseline nursery signature, and/or that the baseline does not fully characterize the variability of each nursery ground. Extending this work by expanding the baseline in number of individuals and including additional nursery grounds for which YOY otoliths are available (e.g. Ligurian Sea and Maltese waters) might provide further insight.

The results of this research show that discrimination of nursery grounds within the Mediterranean Sea is possible using otolith chemistry. However, given interannual variability in the oceanographic conditions, discrimination capability may vary from year to year. Therefore, the origin determination should be adapted to each of the reference years. Bluefin tuna from the 2011 cohort can be assigned to the two major Mediterranean basins (Eastern Mediterranean and Central-Western Mediterranean), whereas discrimination among the four main nursery grounds is possible for bluefin tuna born in 2013 (**Figure 16**).

Table 13. Optimal combination of elements and classification accuracy (estimated by LDA) of YOY bluefin tuna otoliths for 2011 and 2013 cohorts. Area codes correspond to Levantine Sea (LS), southern Tyrrhenian Sea (TY), east Sicily (SI) and Balearic Sea (BA).

Group division	Optimal combination of elements	Year	Classification accuracy
East (LS) / West (BA, TY, SI)	Ba + Li + Mg	2011	100%
East (LS) / West (BA, TY, SI)	Ba + Li + Mn + Sr	2013	91%*
LS / SI / TY / BA	Mg + Mn + Sr + Zn	2013	76%*

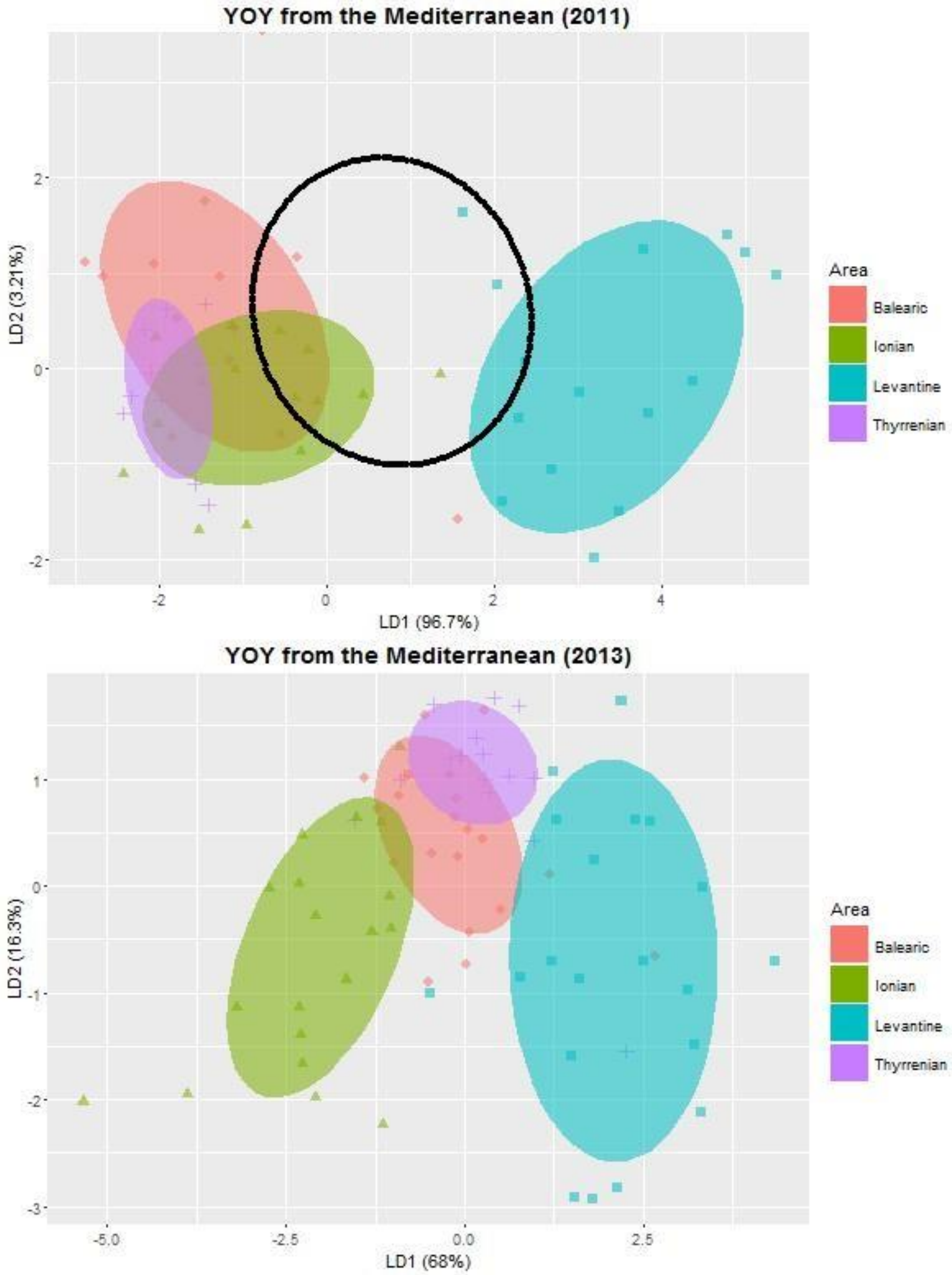


Figure 16. Discriminant analysis of trace element concentration in otoliths of YOY bluefin tuna from the Mediterranean nursery grounds along with otolith near-core signature from juvenile bluefin tuna (2011 year class) of unknown origin collected in the Bay of Biscay(black circle).The ellipses mark 1 SD (67%) confidence levels for the underlying populations**.**

6.4.2. Genetics

Genetic studies in Phase 6 included the origin assignment of the samples collected in the potentially mixing areas using RAD-seq derived SNPs, a work that has already been initiated in the previous phases of the GBYP and microsatellite genotyping of reference samples in the Mediterranean, which was done for the first time in this phase.

6.4.2.1. Origin assignment of juveniles and adults captured at feeding aggregations throughout the Atlantic and over different years

This task consisted on deciphering the map of ABFT mixing in the Atlantic. Two main activities were done: 1) assessing the validity of the optimal minimal SNP panel developed in Phase 5 on spawning adult reference samples, which includes calculating correct assignment rates of currently available panel and developing a strategy to improve these assignments, and 2) genotyping the minimal best available SNP panel in adults from feeding aggregations, which included DNA extraction of about 1000 individuals and processing in a Fluidigm Assay.

355 reference samples (10 larvae and 181 spawning adults from the Gulf of Mexico and 164 spawning adults from the Mediterranean) that have already been genotyped in Phase 5, were analyzed to calculate the assignment power of the currently available RAD-seq derived panel. In addition, 256 of the spawning adult samples used to assess the validity of the panel (179 from the Gulf of Mexico and 87 from the Mediterranean) were RAD-sequenced in order to increase the reference baseline of the Gulf of Mexico from which candidate traceability suitable SNPs are selected. From the RAD-seq catalogs including all already generated samples, the SNPs with the highest F_{ST} values among Northwest Atlantic (including Gulf of Mexico larvae and Cape Hatteras young of the year) and Mediterranean larvae and young of the year were selected.

For each individual, assignment scores (i.e.probability of belonging to each of the baseline populations) have been calculated. For panel validation, assignment scores were calculated for the new 356 reference samples on 96 SNP using a leave-one-out approach with a baseline of 690 individuals, that is, 355 previously genotyped plus 336 newly genotyped individuals (356 genotyped minus 20 that failed) excluding the one being assigned. For determining origin of mixed samples, assignment scores were calculated for the 96 SNP set on 940 samples using the combined set of 691 reference samples (246 from the Gulf of Mexico and 435 from the Mediterranean) as baseline; results are provided considering both 70% and 90% thresholds as “unassigned”.

Assignments of new Mediterranean samples based on the 48 SNPs that best differentiate among Mediterranean areas resulted in 15-25% correct assignment rate (**Figure 17),** confirming that finding SNPs that distinguish the Mediterranean locations is difficult as suggested by the non-genetic differentiation among them. For this reason, SNPs that differentiate among Mediterranean areas where not included in subsequent steps. Also, for the selection of final 96 SNP set, only those that discriminate among Gulf of Mexico and Mediterranean where considered; Cape Hatteras samples (only 16 young of the year) were excluded for being slightly different from the Gulf of

Mexico (see report of Phase 5) and <u>for having chances of arising from another spawning ground</u>. Additional analyses including larvae from Cape Hatteras are required to solve the question of the origin of samples collected in this area. Genotyping of the final set of 96 SNPs in 356 spawning adult samples resulted in 20 samples failing for more than 50% of the SNPs. Average genotyping rate in remaining individuals and SNPs of 99%.

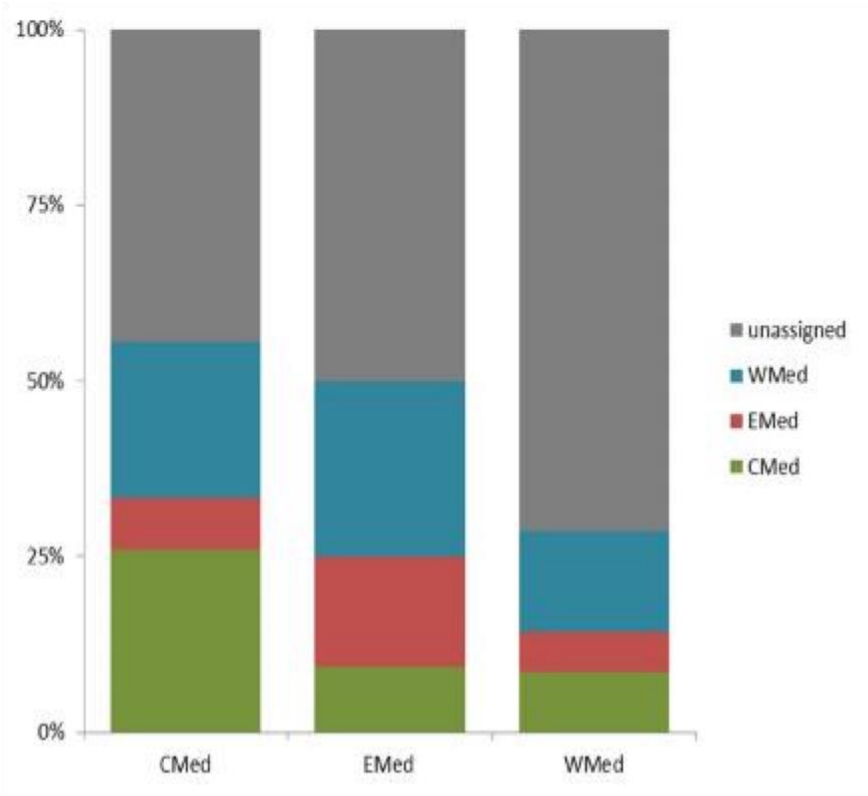


Figure 17. Assignment rates of 114 newly genotyped individuals for 46 SNPs (48 selected to differentiate among Mediterranean populations minus 2 that failed). Individuals with assignment score lower than 90% are considered unassigned.

The set of the best 96 SNPs derived from the RAD-seq analyses was validated in 336 (356 minus 20 whose genotyping failed) newly genotyped spawning adults from the main spawning areas. Using these adults as new reference test samples, new assignment rates were calculated **(Figure 18**). Using 90% as a threshold, 71% of the samples of Gulf of Mexico and Mediterranean origin are correctly assigned and 13 and 2% are incorrectly assigned, respectively. Unassigned samples are 16 and 27% for Gulf of Mexico and Mediterranean respectively. Decreasing assignment score threshold to 70% reduces the number of unassigned samples (5 and 10% for Gulf of Mexico and Mediterranean respectively), but increases the number of incorrect assignments (to 17 and 6% respectively).

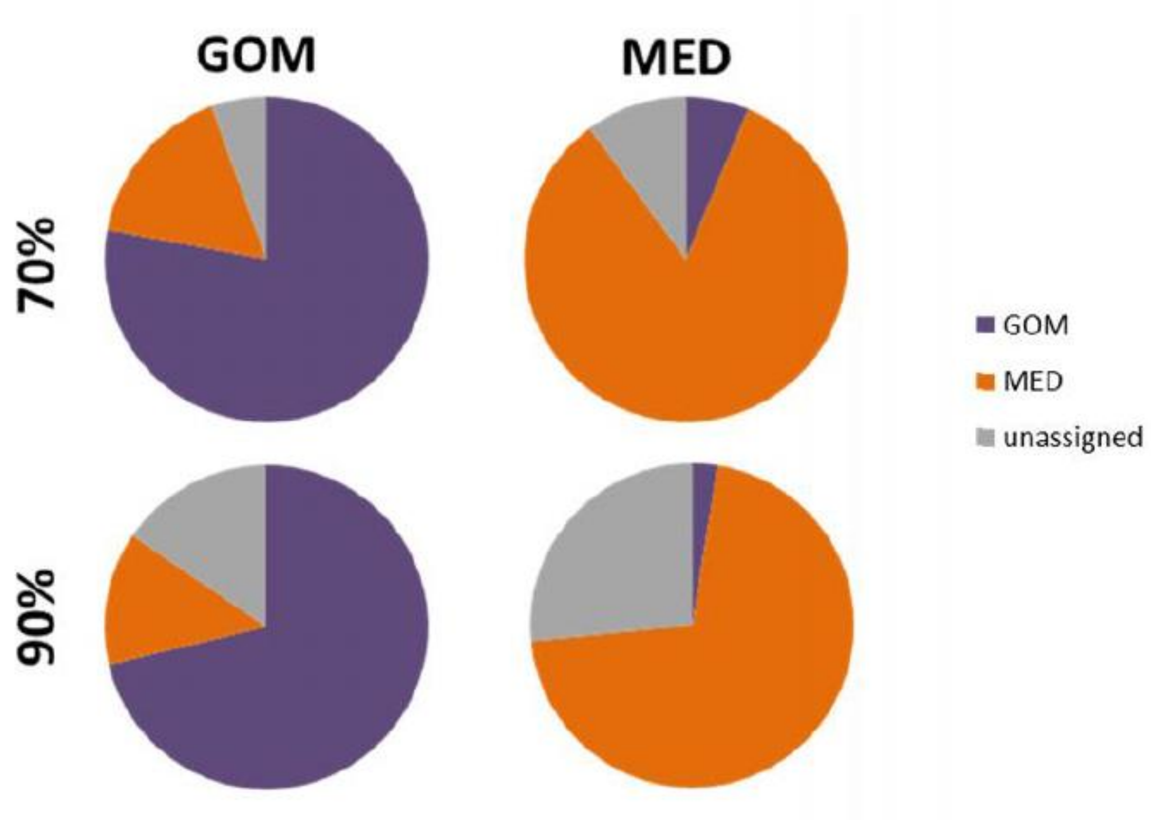


Figure 18. Assignment of Gulf of Mexico (GOM) and Mediterranean (MED) samples based on the best performing 96 RAD-seq derived SNP spanel when samples with assignment scores higher than70% (above) or 90% (below)

From these results and under the current hypothesis of only two possible origins (Gulf of Mexico and Mediterranean), it can be derived that in an assay with samples of unknown origin i) from those assigned to the Gulf of Mexico, 3-6% would come from the Mediterranean, ii) from those assigned to the Mediterranean, 18% would come from the Gulf of Mexico and iii) from those considered unassigned, 40% and 60% would come from the Gulf of Mexico and the Mediterranean respectively. This means that, among the assigned individuals, there will be a slight undersetimation of the proportion of GOM origin.

Samples from twelve different locations throughout the Atlantic have been analyzed and the results are given in the **Figure 19**. Genomic DNA was successfully extracted from 940 individuals, which have been genotyped and assigned to origin

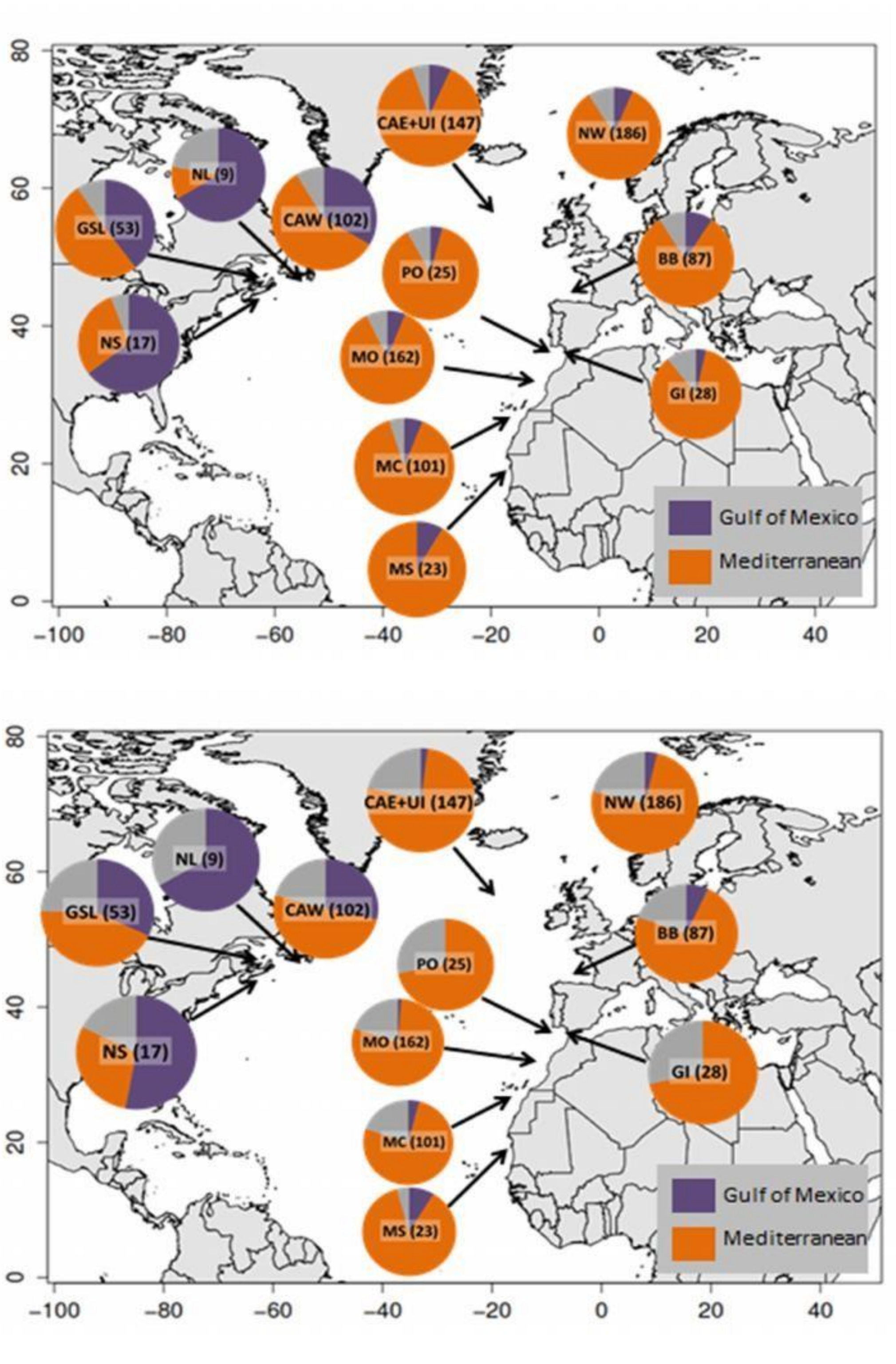


Figure 19. Percentage of samples belonging to each spawning component from the ones captured in each location, with assignment scores of 70% (pannel A) and 90% (pannel B); numbers in parenthesis indicate number of samples per location: Norway (NW), Bay of Biscay (BB), Portugal (PO), Strait of Gibraltar (GI), Morocco (MO), Canarias (MC), Mauritania (MS), Central Atlantic (east of 45ºW, CAE),Central Atlantic (west of 45ºW, CAE), Newfoundland (NL), Gulf of Saint Lawrence (GSL), Nova Scotia (NS).

In both, the GBS and RAD-seq analyses, the number Gulf of Mexico reference samples used for SNP selection was low, meaning that discriminant SNPs were being selected from a few individuals that do not capture the whole genetic diversity of the species. Indeed, self-assignments (that is, assignments on the samples used for SNP selection and or as baseline) provide very high assignment rates (>98% success in the case of RAD-seq) suggesting that the SNPs selected are very good at assigning the samples that were used to select them, but not that good for assigning new samples. This also highlights that reliable assignment success rates should be calculated in new samples, that is, those not used for SNP selection or as baseline. Additionally, the recent discovery of potential new spawning grounds (Slope Sea near Cape Hatteras) could make the assignment to origin even more complicated. Analyses based on more reference samples including larvae and YOY from Cape Hatteras could shed light in this issue.

6.4.2.2. Microsatellite genotyping of reference samples in the Mediterranean

After a discussion at the Bluefin tuna Future Symposium in Monterey (USA), held in the first part of 2016, this task aimed to provide a clear-cut evidence for BFT population structure fulfilling the gap represented by the microsatellite genotyping of reference samples in the Mediterranean at an extensive spatial scale and across a short-term temporal scale to check interannual stability of genetic structure. In fact, previous microsatellite analyses on BFT have never been conducted on experimental designs accomplishing simultaneously the use of reference samples (Larvae or Young-of-the-Year) collected during the same spawning season (from June to September) of multiple consecutive years in the same Mediterranean spawning subareas (Balearic Sea, Tyrrhenian Sea, Central Southern Mediterranean Sea (Sicily/Malta), Levantine Sea).

In addition, this task aimed to overwhelm the methodological constraints represented by the use of a limited number of microsatellite loci (< 20) in the previous analyses and by the use of panels of microsatellites largely different among studies carried out including both the Mediterranean and Gulf of Mexico samples that prevent any fully reliable comparative issue. Thus, a pan-Atlantic study based on a large panel of microsatellite loci (> 20) used to genotype reference samples from both ascertained spawning areas is considered necessary to assess genetic differences within and between each area and provide clear-cut evidence for population structure both in the Mediterranean and in the Gulf of Mexico.

After reviewing literature and primer databases (e.g. http://tomato.bio.trinity.edu) as well as by contacting US and EU scientists, 33 BFT-specific microsatellite loci already used to genetically profile Gulf of Mexico, Atlantic and Mediterranean reference and non-reference samples have been selected. The setup of laboratory protocols for multiplexed PCR and genotyping conditions has been realized in silico and hence experimentally tested at the BMR-genomics service provider.

Preliminary results showed very low, and mostly not significant, differentiation among the samples from various spawning grounds within Mediterranean. The total lack of differentiation among all analyzed samples was further confirmed by the cluster analysis, by the results of DAPC, by the Bayesian approach developed in BAPS (**Figure**

20) and then again confirmed by results of DAPC (**Figure 21**).

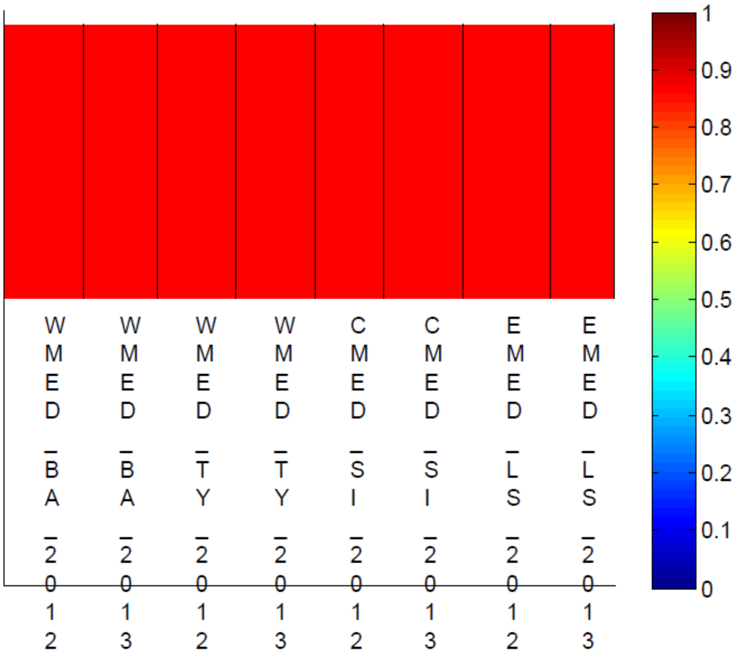


Figure 20. Results of the admixture analysis realized with BAPS.

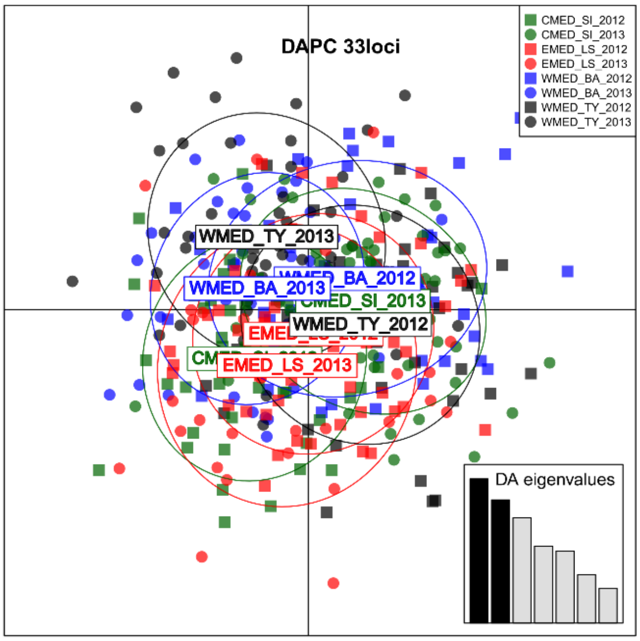


Figure 21. Results of the DAPC analysis performed with Adegenet.

At the end, also the AMOVA analyses displayed the lack of genetic structuring; they indicated that the largest part of the genetic variance is to be attributed to differences among individuals within samples (>99%). No significant differentiation was retrieved when samples were grouped according to the year of collection (2012 vs 2013) or the area of sampling (WMED-BA, WMED-TY, CMED-SI, and EMED-LS) (**Table 14**).

Table 5.7 Results of the analysis of molecular variance (AMOVA).

Source of variation	% of variance	F index	P-value
2clusters			
(WMED_BA_2012+WMED_TY_2012+CMED_SI_2012+EMED_LS_2012)/(WMED_BA_2013+WMED_TY_2013+CMED_SI_2013+EMED_LS_2013)			
among clusters	0.01	F_{CT} = 0.00060	0.48387+-0.01965
Among samples within clusters	0.06	F_{SC} = 0.00055	0.49756+-0.01874
Among individuals within samples	99.94	F_{ST} = 0.00005	0.47605+-0.01547
4clusters			
(WMED_BA_2012+WMED_BA_2013/WMED_TY_2012+WMED_TY_2013/CMED_SI_2012+CMED_SI_2013/EMED_LS_2012+EMED_LS_2013)			
among clusters	-0.02	F_{CT} = -0.00017	0.57674+-0.01380
Among samples within clusters	0.07	F_{SC} = 0.00072	0.42326+-0.01436
Among individuals within samples	99.94	F_{ST} = 0.00056	0.49658+-0.0135

The results obtained with the present experimental design are straightforward to affirm that *T. thynn*us in the Mediterranean is spatially and temporally structured in a panmictic population with high level of genetic connectivity. The analysis of samples of YOY collected over the four main areas of spawning and density of early life stages (e.g. larvae and small-sized YOY: WMED: Balearic Islands; CMED: South Tyrrhenian and Sicilian Channel; EMED: Levantine Sea) and over two consecutive years (2012 and 2013) represents the most solid genetic survey carried out since now for testing the population structure in the Mediterranean BFT using polymorphic species-specific microsatellite loci. This type of molecular markers has proven to be of high resolving power in detecting subtle genetic differentiation in marine fish (see Hauser et al. 2008). All the statistical tests performed, robustly and consistently indicated that genetic differences in BFT Mediterranean reference samples were null or near null.

The lack of genetic heterogeneity recently revealed by the genetic survey carried out by Antoniou et al. (2017) combining data from 16 microsatellite loci and hundreds of genome-wide SNPs obtained from adult farmed BFT collected over Western, Central and Eastern Mediterranean, and by Riccioni et al. (2017) using EST-linked microsatellite loci on medium and large BFTs from the same areas are coherent with the pattern here obtained and with the null genetic heterogeneity detected.

This analyses further corroborated the results of other previous analyses (using SNPs) indicating there is no population structure within the Mediterranean.

6.4.3. Otolith shape analyses

Previous studies showed that variation in otolith shape is useful for discriminating between adult (>200cm) bluefin tuna from the eastern and western Atlantic. The baseline samples used in that study comprised of 50 adult fish from the Canadian fishery (Gulf of St Lawrence, Newfoundland and the Scotian Shelf) and 50 adult fish from the central Mediterranean (Malta) collected during the spawning season. An objective of GBYP Phase 5 and 6 was to refine the baselines used to characterise the western and eastern stocks by including adults from the Gulf of Mexico spawning grounds and adults from a wider geographical range within the Mediterranean collected during the spawning season (May and June). The sampling also targeted a broader size range of fish (>170cm).

The task aimed to use shape analysis of otolith outlines to distinguish between the two spawning populations to determine if otolith shape descriptors provide a reliable marker of spawning origin and to use this classification to determine the likely origin of estimate stock composition of mixed samples collected in the Atlantic in 2011, 2012 and 2013.

Seventy nine samples of unknown spawning origin were obtained from the GBYP database. These fish were collected from three locations in the eastern Atlantic: the Straits of Gibraltar, the coast of Portugal and Morocco in 2011, 2012 and 2013. These individuals were chosen for inclusion in this analysis because stable isotope measurements were also available allowing comparison of assignments in the subsequent integrated analysis task. The classification functions developed from the baseline samples were used to assign these individuals to populations.

Previous studies discriminated between bluefin tuna from the western (Canada) and eastern Atlantic (Malta) with a classification success of 82% (83% for the western samples and 82% for the eastern samples). In this analysis using baseline samples from the Gulf of Mexico spawning grounds and additional sites within the Mediterranean, the classification success decreased to 76% for the western Atlantic and 80% for the Mediterranean. The original baseline samples from Canada and Malta may have had more distinct environmental histories (e.g. have resided in the west or east Atlantic for the majority of their lives) compared to the more extensive baselines used in the current analysis. Although there is significant variation in otolith shape between the Gulf and Mexico and the Mediterranean spawning populations, a classification function based on otolith shape descriptors alone provides only moderate discrimination between the groups.

Regarding mixed analysis, the misclassification rate (out of bag error) associated with the random forest model was 28%. When individuals in the mixed samples were assigned to populations using the random forest model of shape descriptors, the percentage of fish that were estimated to be of Mediterranean origin was lower than that previously reported by Brophy et al (2015) **(Table 15).** The probabilities of group membership was <70% for the majority (73%) of the individuals.

The analysis of the refined baseline samples confirms that there is considerable overlap in otolith shape between the two spawning populations. On its own, otolith shape does not provide a sufficiently reliable marker of spawning origin and estimates of stock composition based on otolith shape are subject to a large degree of error. It appears that due to the strong influence of environmental history on otolith shape, the technique may be a more powerful for characterising contingents within both populations that follow different migration pathways.

Table 15. Summary of bluefin tuna mixed samples that were assigned to putative populations using a classification function based on otolith shape descriptors

	2011	**2012**	**2013**	**% east new baselines**	**% east Brophy et al 2015**
GI	198.5 - **1**			100	94.3*
MO	230.5 *220-241* **2**	209.9 *187-225* **18**	214 *176-236* **30**	66.0	78.6
PO	207 *183-235* **16**	210.8 *191-281* **12**	- - **0**	78.6	91.4

6.4.4. Integrated approach to stock discrimination

Various genotypic and phenotypic population markers have been used to distinguish between bluefin from the eastern and western Atlantic. However, there is a degree of uncertainty associated with each method of population assignment. In GBYP Phase 5, comparisons of individual assignments using genetics, isotopes and otolith shape methods revealed disagreement between the three methods. It may be possible to improve overall accuracy of stock assignment by using a combination of population markers in an integrated stock mixture analysis. This task employed the data and material produced by the integrated analysis task from Phase 5 and additional data generated by other tasks in Phase 6 to develop a multi-marker method for discriminating between bluefin tuna from the Gulf of Mexico and Mediterranean spawning populations.

In the baseline samples, 57 of the Gulf of Mexico fish and 102 of the Mediterranean fish were analysed using chemistry (d13C, d18O), shape and genetics. For the genetic analysis nucleotide sequences were available for 48 individual SNP loci. Gene frequencies were compared between the two populations using Chi square analysis. Loci which varied between populations were included as categorical predictors in three classification models using random forest: a) genetics only; b) chemistry and genetics; c) chemistry, shape and genetics. The classification error associated with each model was compared using out of bag estimates of error rates.

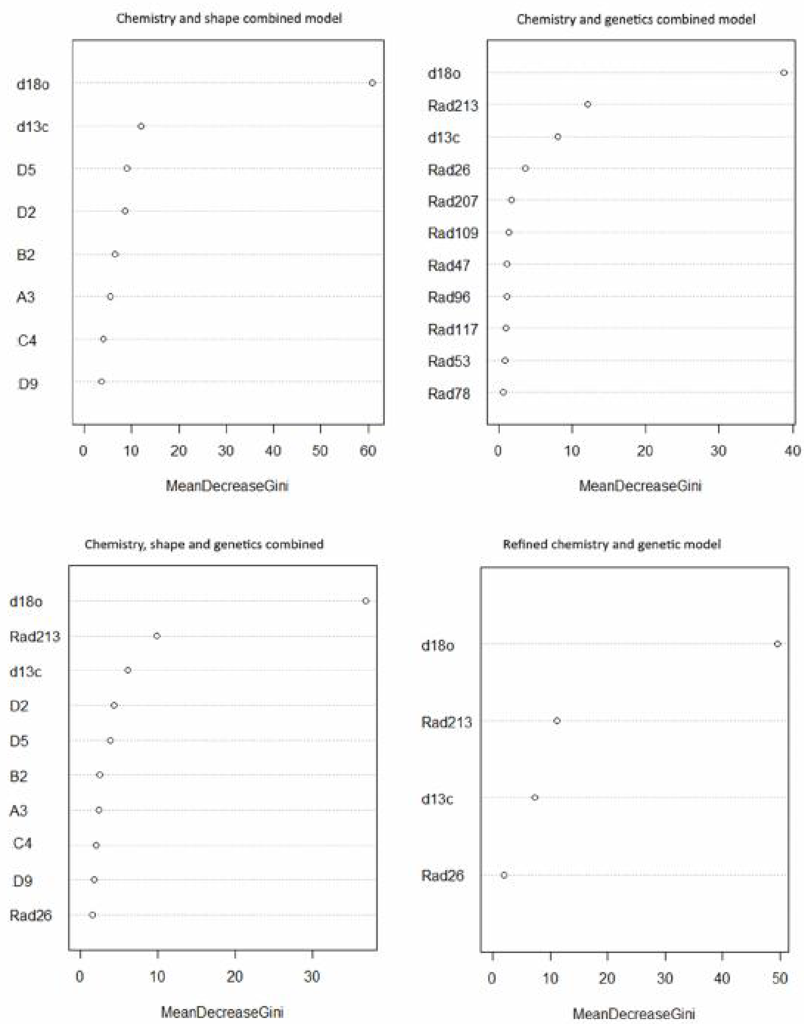


Figure 22. Variable influence plots showing the relative importance of each of the variables in the combined chemistry and shape model (top left), the combined chemistry and genetic model (top right), the combined chemistry, shape and genetics model (bottom left) and the final refined chemistry and genetic model which produced the lowest error rate (bottom right).

The three way integrated model (chemistry, shape and genetics) did not improve the classification success (error rate 5.1%). This again suggests that the otolith shape measurements do not provide complementary information about natal origin but may provide an alternative indicator of migratory history. Combining chemistry and genetics improved the mean individual assignment probabilities by 6% for the Gulf of Mexico samples and 0.92% for the Mediterranean samples compared to the chemistry only model. Improvements relative to the genetics only model were 14% for the Gulf of Mexico samples and 20% for the Mediterranean samples. This shows that Rad SNP genotypes can complement stable isotope measurements and improve the accuracy of natal origin estimates. The baseline samples used in this analysis showed relatively large differences in stable isotope measurements with little overlap between the Gulf of Mexico and Mediterranean samples. The influence of each variable in a combined model is shown in a **Figure 22.**

6.4.5 Age determination analyses

The biological analysis of this project included direct ageing to obtain age composition of Atlantic bluefin tuna catches and age composition of the population structure samples. The bluefin tuna Species Group has emphasized the need for annual age length keys (ALKs) because it was found that cohorts of bluefin tuna can be more easily detected and followed when annual ALKs were used.

In previous phases of the project, a stratified sampling by size class, geographical location, month of harvest and fishing gear was used in the selection of samples to obtain a robust ALK for 2011. In the Phase 6 the activity of aging was carried out on the available hard parts already collected in 2012 in order to produce two annual ALKs with good sampling coverage. In the Phase 6 the existing 2012 ALK, which already had 39 calcified structures read in previous phases, was completed with the analysis of 325 new ones.

In the 2012 ALKs, built with the otolith samples analyzed in the current phase and in previous ones, sizes unusually low for ages 8 and 9 are also observed, coming from different catch locations (although most of them from the Mediterranean). This fact is also observed in the spine ALK (**Figure 23**). Those specimens correspond to the 2002/2003 year classes, which have been considered to be extraordinary abundant. This lower length at age may be related to an effect of density-dependence and/or to a lower growth in the Mediterranean bluefin tuna. No differences were observed in the mean SFL by age for both structures based ALKs, although the otoliths ALK presented greater length variability by age.

The different ALKs built by ocean/sea present also some variability of sizes by age and numerous length bins without age. It is necessary to analyze a greater number of samples so that the annual keys by ocean/sea have an adequate number of samples per size. Mean length at age differences were observed for ages 6 to 9 between both ALKs and with ICCAT adopted growth curve, with higher values for the Atlantic Ocean based ALK. A high standard deviation also appeared at ages 8 and 9, notably in the Mediterranean ALK.

Otoliths Estimated age

0-20% | 20-50% | 50-100%

SFL (cm)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total n
40-50	100																			6
50-60			100																	1
60-70		83	17																	6
70-80		17	33	50																6
80-90			40	60																5
90-100			67	33																3
100-110			17	50	33															6
110-120					60	20	20													5
120-130					14	57	29													7
130-140				5	14	23	36	9	9	5										22
140-150					11	6	11	17	33	22										18
150-160					5	15	30	40	10											20
160-170							15	46	31		8									13
170-180								44	22	22	11									9
180-190								25	17	8	17	25	8							12
190-200								4	30	43	17	4								23
200-210								6	16	32	16	16	4	8	2					50
210-220								11	11	20	18	31	4	2		2				45
220-230									8	16	20	44	8	4						25
230-240									18	6	18	29	6	6	6	12				17
240-250									7	21	14		29		7		14		7	14
250-260													25	50	25					4
260-270													33		33				33	3
270-280																100				1
280-289																		100		1
Total	6	6	9	11	12	14	21	35	44	51	34	42	14	9	5	4	2	1	2	322
Mean SFL	41	65	81	94	127	136	142	173	188	201	211	215	229	222	237	237	245	281	256	
SD SFL	0.8	5.6	16	17	16	11	14	24	31	24	17	12	23	22	23	25	1.7		9.7	

Spines Estimated age

0-20% | 20-50% | 50-100%

SFL (cm)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total n
40-50	93	7																		14
50-60	17	83																		6
60-70		100																		12
70-80			100																	13
80-90		8	67	25																12
90-100			29	57	14															14
100-110			8	69	23															13
110-120				38	46	15														13
120-130				6	65	29														17
130-140				5	18	55	23													22
140-150					12	35	41	6	6											17
150-160						33	41	19	7											27
160-170							38	31	15	15										13
170-180							23	31	38	8										13
180-190							20	40	10	30										10
190-200								19	38	25	19									16
200-210								3	38	41	7	10								29
210-220									5	55	27	5		9						22
220-230									11	33	56									9
230-240											17	67	17							6
240-250											20	40	20	10	10					10
250-260												50					50			2
260-270														25	75					4
270-280																				0
Total	14	19	26	27	28	34	33	22	30	37	19	13	3	4	4	0	1	0	0	314
Mean SFL	42	63	82	103	121	139	153	173	191	204	217	230	240	236	258		251			
SD SFL	4.7	6.4	7.5	11	13	12	14	16	20	15	13	17	4.9	26	8.8					

Figure 23. Age length key for Atlantic bluefin tuna caught in 2012 built up with samples coming from several phases of the project. Numbers represent percent by number by 10 cm length class (straight fork length, SFL). Upper table for otoliths and bottom table for spines. Mean SFL and standard deviation (SD) by age are shown.

6.4.6 Larval studies

Larval surveys were included in the preliminary list of GBYP research activities recommended by the SCRS at the early beginning of the GBYP approval process, even if with a low priority. Later on, the Commission excluded any larval survey from the programme, even if the first discussion on the budget included the larval studies for three years. The exclusion was shared also by the GBYP Steering Committee.

Studies carried out during the past years on early life stages of top predator species, as tunas, demonstrated that these studies could be useful for improving our understanding of the population dynamics of harvested stocks. This reflects the hypothesis that early life dynamics is one of the main drivers influencing population fluctuations. This information has been incorporated since years in the WBFT stock assessment, particularly as relative abundance indices of the spawning stock. Therefore, there is the potential for scientists to contribute with additional indices and data streams that could contribute to stock assessments, such as larval survival index; spawning and larval habitat quality predictions; population genetic structure, abundance estimates and stock mixing (through kinship analysis).

Under the context of ecosystem-based fisheries management, early life history studies can provide understanding of the structure and trophodynamics of plankton assemblages and sources of environmental variability that can feed into ecosystem models. They can also provide indicators of the plankton assemblages that are relevant for ecosystem-based fisheries management and the effects of climate change, if sufficient data about all main components can be provided.

Pursuant to the recommendation of the Steering Committee and the ICCAT SCRS in 2015, GBYP organized a dedicated Workshop on larval studies and surveys in Phase 6. The workshop was held at the ICCAT headquarter in Madrid, on 12-14 September 2016 and was attended by around 20 eminent scientists in bluefin tuna larval biology from EU, USA and Japan.

During the workshop, a review of the available knowledge on the bluefin tuna early stages was presented, for both the Mediterranean Sea and the Gulf of Mexico, along with the results from the latest studies. Current and recent research project were presented and the sampling methodologies that were followed in each study were discussed in detail, as well as common problems that were encountered. A special attention was put on the spawning and larval habitat, as well as on environmental dependencies. The difficulties for morphologically identifying bluefin tuna larvae were deeply discussed, even if some doubts are still to be solved according to some scientists, while there are no doubts when it is possible to have a genetic analysis. The progress and limits in using the larval index was also discussed, as well as its potential use as an abundance index for the purpose of the bluefin tuna stock assessment. The GBYP presented an overview of potential research needs and opportunities for the larval surveys (see document SCRS 2016/176 in **Annex 1b document no. 15**).

The participants also discussed the possibilities for carrying out a joint larval study, with standardised methodology on all spawning grounds in the Mediterranean. It might also provide information on early stages of ICCAT species other than bluefin tuna and therefore contribute to the assessment of different stocks. Terms of reference of the future larval survey working group were drafted, identifying the goals and initial work plan, with the intention for this new group to be presented in the SCRS meeting and therefore available to different species working groups. The report is attached in **Annex 1a document no. 29**, provided as SCRS/2016/206.

7. Modelling approaches

The initial, short-term ICCAT GBYP objective which was approved by the Commission in 2008 was to carry out operating modelling studies from year 4, with a total budget of 600,000 Euros. So far, with 88.1% of the funds (a total of 528,853 Euros, including the budget amount set for Phase 6, equal to 194,000 Euros), the ICCAT GBYP carried out many modelling activities since Phase 2, following the recommendations of the Steering Committee and the SCRS. It is very clear that the general objectives set for the modelling studies in these first Phases were largely accomplished so far, taking into account the proportion of the available budget. Furthermore, the modelling plan was fully revised and now it has been extended up to 2021 as recommended by the SCRS, and as it was endorsed by the Commission.

The final reports of the modelling activities were presented at the SCRS BFT Species Group meeting and are available on the ICCAT GBYP web pages http://www.iccat.int/GBYP/en/modelling.htm.

7.1 Objectives

Under the GBYP the modelling programme addresses objective 3: “Improve assessment models and provision of scientific advice on stock status through improved modelling of key biological processes (including growth and stock-recruitment), further developing stock assessment models including mixing between various areas, and developing and use of biologically realistic operating models for more rigorous management option testing”.

In addition, in 2012 the Commission requested the SCRS (Doc. No. PA2-617A/2012 COM) to conduct a stock assessment in 2015 and to:

a) Develop a new assessment model allowing the inclusion of the last updated knowledge on the biology and ecology of bluefin tuna, in particular life-history parameters, migration patterns, and aiming at identifying and quantifying uncertainties and their consequences on the assessment results and projections.

b) Release a stock status advice and management recommendations, supported by a full stock assessment exercise, based on the new model, additional information and statistical protocols mentioned in points above and on which basis all actions may be adopted and updated by the Commission through the management plan to further support the recovery.

The GBYP activities in the first Phases were consistent with the objectives, within the timeframe set by the Modelling MSE Core Group.

7.2 Phase 6 activities for modelling in support of BFT stock assessment

Activities in the Phase 6 were mainly continuation of the work already started in the previous phases. A follow up contract for the MSE technical assistant was provided to the Dr. Tom Carruthers, the same expert who initiated the work, for developing the Operating Model and MSE framework and related code. According to the recommendation of the Steering Committee, a contract for the MSE coordinator was suspended, given its low priority in this Phase.

A third meeting of the ICCAT GBYP Core Modelling MSE Group was held in Madrid on 14-15 November 2017. Following the decision of the ICCAT SCRS on building modelling capacities, GBYP organized a short training course on Virtual Population Analysis (VPA) with theory and application to bluefin tuna. It was held in Miami, (USA), from 6-10 February 2017.

An ICCAT GBYP multi-annual modelling work plan was proposed at the Monterey CMMG meeting, based on the conclusions of the Gloucester meeting. A main objective of MSE is to provide advice that is robust to uncertainty, and requires a number of steps:

1. Identification of management objectives and mapping these into statistical indicators of performance or utility functions;
2. Selection of hypotheses for considering in the Operating Model (OM) that represents the simulated versions of reality;
3. Conditioning of the OM based on data and knowledge, and weighting of model hypotheses depending on their plausibility;
4. Identifying candidate management strategies and coding these as Management Plans;
5. 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
6. Identifying the Management Plan that robustly meet management objectives.

These steps require the engagement of stakeholders to evaluate alternative management actions and the risks of not meeting management objectives. An OM (Operating Model, a mathematical simulation model) has to be coded up to allow the consequences of the improvement of knowledge, collection of data and implementation of management measures to be evaluated.

This requires the OM to be implemented in software. Therefore under previous phases of the GBYP M3 a prototype OM has been implemented and is available in the software repository https://github.com/ICCAT/abft-mse. This allows multiple developers to collaborate on its development. In addition a manual has been provided which forms the basis of a Software Development Plan (SDP) for future development.

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

The objectives for the activities in GBYP Phase 6 were the following:

1. Continue the development of the Operational Model (OM) based on the Management Strategy Evaluation (MSE) trial specifications document.
2. Develop a test unit to validate the age-based movement model.
3. Work with third parties to add Management Plans (MPs) to the MSE framework including empirical control rules and simple stock assessment methods
4. Run the MSE in collaboration with BFT Species group.
5. Collaborate with SCRS to develop interactive graphics (i.e. Shiny apps) to communicate MSE results to stakeholders based on the performance metrics of the trial specifications document.
6. Work with others to update and maintain the meta database of the available bluefin data and knowledge https://github.com/ICCAT/GBYP-MetaDB
7. Work with SCRS to help develop 3 prototype examples.

During the BFT Data Preparatory Meeting in July 2016, the progress of simulation testing a multi-stock model with age-based movement was presented as a paper SCRS/2016/144 (in **Annex 1a document no. 32**). The issues arising from the preliminary conditioning of operating models for BFT were presented as well, and are available as SCRS/2016/145 (in **Annex 1a document no. 33**).

During the 2017 BFT Data Preparatory meeting, a further scientific paper was presented on calculating population-wide spatial and seasonal relative abundance indices for use in operational modelling, provided as SCRS/2017/019 (in **Annex 1a document no. 37**).

7.1 Modelling technical assistant

A contract for developing the Operating Model and MSE framework and related code was provided to the Bleu Matter Science (to be developed by Dr. Thomas Robert Carruthers) in Phase 6, who continued the modelling technical work initiated in Phase 4 and further developed in Phase 5 (under a contract to the University of British Columbia, CAN, but always under the direct responsibility of the same expert).

The focus of this contract was finalizing the technical aspects of the operating modelling and producing a user-friendly and fully functional MSE framework that could provide a basis for feedback and collaboration from a wider group of stakeholders. In this regard, a number of major milestones were achieved in this contract. Following the data preparatory meeting the fleet structure and data formats were finalized and the meta-database was updated. The fishery, survey, tagging and stock of origin data were formatted for use with the operating model. A SCRS paper that provides a full account of the derivation of the 'master index' that is central to the operational modelling was also provided presented on the BFT Species Group. The online meta-data summary was linked to the corresponding sources of data in the GitHub repository.

With regards to operating models, a final operating model structure Modifiable Multistock Model - (M3 v1.3) was designed following feedback from the Core Modelling Group including a new model initialization by stock reduction analysis to account for catches before 1960. The new operating model was simulation tested to check for coding errors, identifiability and to establish suitable data weightings and the trial specifications document was updated following feedback from the Core modelling group. M3 software design specifications were developed and are attached in **Annex 1a document no. 35**, as well as the M3 user guide, which is attached in A**nnex 1a document no. 36**.

Regarding the MSE development, the 18 reference operating models were fitted to data and reproducible R scripts were made available that describe this process. A standard operating model fitting report was developed in R markdown and these were generated for each reference operating model. A comprehensive set of R functions were developed to allow for the simple and rapid design of operating models, fitting of operating models to data, design of management procedures, specification of performance metrics and the running of Management Strategy Evaluation. All of the R code, data and objects were compiled into a single R package (ABTMSE) with complete documentation for all functions, objects and data to be used in MSE analyses. The raw data, R scripts, Reports, help documentation and the R package were assembled in a single directory which can be downloaded from the ICCAT GitHub repository. The ABTMSE Software design specifications v2.1.0. are attached in **Annex 1a document no. 34**.

As regards to the documentation, an extensive user guide was developed in R Markdown that describes the file structure, the project and guides users through the various functions of the R package including worked examples of the 7 steps of MSE development. Also, a fully documented website was produced using 'pkgdown' that can act as the front page of the ICCAT ABFT-MSE repository and has links to various documentation including all the functions and objects of the R package.

The final report is available in **Annex 1a document no. 31**.

7.2. ICCAT GBYP Core Modelling MSE Group

The role of the ICCAT GBYP Core Modelling and MSE Group is defined as follows:

a) Provide technical oversight and advice on the MSE process to the SCRS

b) Provide annual review of progress against work plan and report to SCRS and Commission

c) Review technical contributions and outputs to the work program and advise the secretariat on satisfactory completion of tendered contracts.

d) Advise the secretariat and GBYP Steering Committee on out-of-session revisions to work program, where necessary and appropriate.

There were institutional replacements in the membership of the ICCAT GBYP Core Modelling and MSE Group (ex ICCAT GBYP Core Modelling Group) in the last three years, taking into account the two GBYP Core Modelling and MSE Coordinators, the new SCRS Chair and the new WBFT rapporteur. The Group in Phase 6 has the following members: Tom Carruthers (expert and MSE Technical Assistant), Polina Levontin, Richard Hillary, Toshihide Kitakado, Haritz Arrizabalaga, Doug Butterworth and *ex-oficio* members: David Die (SCRS Chair), Clay Porch (ABFT Chair), Gary Melvin (WBFT Rapporteur), Sylvain Bonhommeau (EBFT Rapporteur), Laurie Kell (ICCAT Population Dynamics Specialist), Paul De Bruyn (ICCAT Research and Statistics Coordinator), Antonio Di Natale (ICCAT GBYP Coordinator) and Miguel Neves dos Santos (ICCAT Scientific Coordinator).

A third meeting of the ICCAT GBYP Core Modelling MSE Group was held at ICCAT headquarters in Madrid on 14-15 November 2017. This meeting aimed to review the work done by the Core modelling group since the last meeting of the group that was held in Monterey in February 2016. The Core modelling group reported extensively on progress to the Bluefin tuna working group in July 2016, at which time the final decisions on data to be used for the conditioning of the operating model were agreed upon in nearly all respects. At the SCRS species group meeting in September 2016, the Core modelling group provided a summary of progress but there was limited opportunity for detailed discussions.

The Group reviewed and further discussed the recommendations that were given on the tRFMO meeting which preceded this one (from 1-3 November). It was recognized that ABFT OM is amongst the most complex of such existing models. It is also recognized that it is important to show stakeholders that what kind of uncertainties are incorporated in the model, and that they cover hopefully most of the common major uncertainties. The group also recognized that MSE can also be used to show managers the benefits of various research activities. Those benefits may include economic factors or be qualitative such as improve confidence in management. It was also suggested that it would be desirable to start considering the inclusion of MSE as a topic for a CAPAM workshop. The Group examined the MSE trials (North Atlantic Bluefin MSE trials specification document, including performance statistics and their relation to Kobe plot measures) and discussed methods to prioritize the importance of different sources of uncertainty to develop a hierarchy of MSE trials. The conditioning of trials were also reviewed, based on the 2014 VPA assessment which was used as a base case and it was finally confirmed.

Regarding the future commitments, it was decided that the ICCAT GBYP Core Modelling MSE group prepare a brief document explaining the final decisions made for the OM to the BFT data preparation meeting for endorsement. At this meeting hopefully at least three groups will be identified to develop candidate MPs. Representatives of this group will meet with the Core modelling group in June 2017 to review the results for an initial set of MSEs so that further results can be presented to the SCRS in September 2017. These MSE trials and their results are meant to be used to start a dialog with stakeholders. The MPs concerned are not intended to represent the full set of MPs to be used for the MSE.

The report of the third meeting of the ICCAT GBYP Core Modelling MSE group is provided is attached in **Annex 1a, document no. 38.**

7.3 VPA Training course

Following the recommendation of the ICCAT SCRS on building modelling capacities, endorsed by the Commission in 2015, and the recommendation of the Steering Committee, the GBYP organized a short training course on Virtual Population Analysis (VPA) with theory and application to bluefin tuna. It was held in Miami, USA from 6-10 February 2017, in the premises of the Rosenstiel School of Marine and Atmospheric Science (RSMAS). Out of 13 candidates that applied for the training course, 11 were selected, mainly based on the availability to participate in the 2017 bluefin tuna stock assessment exercise. The Course was taught by three experienced instructors: Ph.D. Laurence Kell, Ph.D. Clay Porch and Ph.D. Ai Kimoto. A photo took during the Course is attached below (**Photo 1**). The agenda of the Training course is attached in **Annex 1a, document no. 39** and the list of participants in **Annex 1a, document no. 40.**

Photo 1. Instructors and participants to the ICCAT GBYP training course on Virtual Population Analysis

The course provided an introduction to the mathematical theory behind tuned virtual population analysis, the calculation of biological reference points, and projecting the abundance of the stock for a range of scenarios , e.g. for different catch quotas and model assumptions. Participants worked in teams to develop simple assessment and projection models in Excel and to learn the basic concepts. Afterwards, they operated in a workshop environment similar to an actual bluefin tuna stock assessment where they were prepared for the 2017 assessment by conducting their own analyses using the VPA-2BOX and PRO-2BOX software, and prepared a summary of the proposed management advice. Techniques for modeling two intermixing stocks were discussed. Exercises were conducted in both MS Excel and R. VPA and the assumptions behind were introduced and explained, focusing on data requirements, assumptions, uncertainty, diagnostics, interpretation of results and advice. Examples were mostly based on the last bluefin assessment.

The course prepared participants to:

- Conduct exploratory data analyses of the types of data required to provide advice.
- Understand the assumptions underpinning stock assessment.
- Be aware of how uncertainty impacts the robustness of advice.
- Participate fully in the preparation for the ICCAT stock assessment working group
- Help in formulating advice

8. Legal framework

The enforcement of the ICCAT Rec. 11-06, which allows for a “research mortality allowance” of 20 tons/year for GBYP and for the use of any fishing gear in any month of the year in the ICCAT Convention area for GBYP research purposes, finally helped GBYP in carrying out both tagging and biological sampling activities. The ICCAT Secretariat, on 22 May 2012, issued a first circular (no. 2296/2012), establishing the rules and the details for the enforcement of Rec.11-06, including the official form for reporting the RMA and the first list of authorized institutions (20 entities). Another circular (no. 2279/2013) was issued on 28 May 2013, including 33 authorised entities. The third circular (no. 2180/2014) was issued on 23 April 2014, with a list of 36 authorised entities. The forth circular (no. 3203/2015) was issued on 26 May 2015, with a list of 32 entities. The sixth circular (G-0745/2016) was issued on 10 June 2016, with the list of 20 entities. For the purpose of covering all the activities in the second part of GBYP Phase 6, it was updated on 10 October 2016 (no. 1356/2016), with the list of 31 entities and then again on 29 November 2016 (no. 1574/2016) with the list of 32 entities.

A total of 231 ICCAT GBYP RMA certificates have been issued from 2012 to February 2017, using 11,519.60 kg of bluefin tuna (equal to 1915 fish). 72 RMA certificates were issues in Phase 6, using a total of 856.01 kg corresponding to 550 fish. RMA used quantities in previous years (5,039.49 kg in 2012, 4,392.76 kg in 2013, 887.78 kg in 2014, 324.71 kg in 2015 and 874.86 kg in 2016) were officially communicated to ICCAT Statistical Department for the inclusion in the official ICCAT BFT catch table.

The ICCAT CPCs, in general, supported from a practical point of view the GBYP field activities, as established by the Commission. Only few exceptions were noticed about the late issuing of the permit for carrying out biological sampling activities in some areas.

9. Cooperation with the ICCAT ROP

The GBYP coordination, together with the ICCAT Secretariat, is maintaining and improving the contacts with the ICCAT ROP observers, for strengthening the cooperation and providing opportunities. The ICCAT ROP observers are engaged for directly checking bluefin tuna at the harvesting for improving the tag recovery and reporting, but also for noticing and reporting any natural mark. Specific forms were provided to ROP. The GBYP Coordinator regularly participated to the ICCAT ROP observers training courses, specifically training them for the tag recovery and reporting, up to Phase 5; in Phase 6 this cooperative participation was not authorised. ICCAT GBYP tag awareness material is regularly provided to ICCAT ROPs.

The contacts between ICCAT ROPs and ICCAT GBYP are usually in real time, always through the ICCAT Secretariat, which is duly informed of all contacts and procedures. ICCAT ROPs are also helping for identifying the right persons for providing the rewards for the recovered tags.

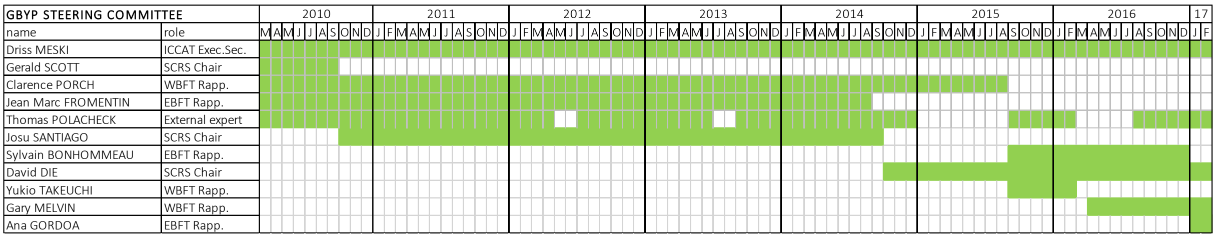
ICCAT ROPs are improving their tag reporting year after year and this cooperation could be possibly extended also to genetic sampling in Phase 7, after assessing both their availability and the good-will of the tuna farm owners.

10. Steering Committee Activities

The GBYP Steering Committee in the Phase 6 was composed by the Chair of SCRS, Ph.D. David Die, the BFT-W Rapporteur, Ph.D. Gary Melvin, the BFT-E Rapporteur, Ph.D. Sylvain Bonhommeau (who was replaced by Ph.D. Ana Gordoa from January 2017), the ICCAT Executive Secretary, Mr. Driss Meski, and the external expert, Ph.D. Tom Polacheck, who was contracted for this duty. **Table 16** shows the different composition of the ICCAT GBYP Steering Committee since the beginning of the programme (according to the official contracts for the external member only). The changes in the SC members, which are logical according to the current institutional components, sometimes created different views for some GBYP activities.

The Steering Committee members have been constantly informed by the GBYP about all the initiatives and they are regularly consulted by e-mail on many issues. A monthly report was provided to the Steering Committee by the GBYP Coordinator. The activity of the Steering Committee included continuous and constant e-mail contacts with the GBYP coordination, which provided the necessary information.

Table 16. Composition of the ICCAT GBYP Steering Committee since the beginning of the programme.



In Phase 6 the Steering Committee held one meeting (on 30-31 July 2016), discussing various aspects of the programme, providing guidance and opinions for adapting the plan for Phase 6. The finalised report of the GBYP Steering Committee meeting is available on http://www.iccat.int/GBYP/en/scommittee.htm and attached in **Annex 1a, document no. 3**.

11. Funding, donations and agreements

The Atlantic-wide Research Programme for Bluefin Tuna, according to the Commission decision in 2009, is voluntary funded by several ICCAT CPCs. The annual budgets are on http://www.iccat.int/GBYP/en/Budget.htm

So far, up to the first six Phases, GBYP received and used only 62.22% of the funds originally approved for the same time period (11,869,782 euro[8] against 19,075,000 euro). In Phase 6, the budget had the following funders (in order of contribution already received):

European Union (grant agreement)[9]	Euro	1,190,000.00
United States of America (donation)	Euro	119,582.24
Japan (donation)	Euro	62,860.40
Tunisia (donation according to quota)	Euro	58,336.51
Turkey (donation according to quota)	Euro	57,138.43
Libya (donation according to quota)	Euro	54,068.52
Kingdom of Morocco (donation)	Euro	53,324.00
Norway (donation)	Euro	20,000.00
Canada (service agreement)*	Euro	18,994.52
Albania (donation according to quota)	Euro	5,143.59
Korea (donation according to quota)	Euro	4.442.65
Chinese Taipei (donation)	Euro	3,000.00
Popular Republic of China (donation according to quota)	Euro	2,106.80
Iceland (donation according to quota)	Euro	1,708.54

[8] For Phase 6, due on-going activities, the amount is based on the budget.

[9] The amount represents the anticipation received, over a total EU contribution of 1,700,000 euro.

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 Phase 4 and 5. Contributions for previous GBYP Phases are still pending from some ICCAT CPCs.

The lack of a stable and reliable multi-year funding system is one of the major problems for GBYP, because this fact prevents a proper planning of all activities and contracts at the beginning of each Phase. The GBYP Steering Committee and the SCRS several times recommended 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, 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 will be certain and confirmed only at the very end of each Phase. This fact implies a continuous attention to the effective budget availability at each step of the programme by the Coordination and the impossibility to operate with multi-year contracts for multi-year activities.

The Atlantic-wide Research Programme for Bluefin Tuna is a very complex programme and its activities concern all stakeholders. When it was approved by the Commission, the reason was that this programme is necessary for improving the scientific knowledge about this species and this is the difficult and challenging work that GBYP is carrying on, following the strategy recommended yearly by the Steering Committee and the SCRS, but also by the Commission. As a consequence, the GBYP needs the cooperation of all stakeholders and all countries to fulfil its duties in the best possible way. This need was perfectly identified by SCRS and the Commission during the preliminary evaluation of the Programme and then reinforced by the mid-term evaluation and by the second external review. Therefore, GBYP is managing to work with all stakeholders, making them aware of the programme and its activities and getting them directly involved when necessary.

A formal agreement of collaboration for research activities to be developed under the GBYP and particularly on tagging was established with the WWF Mediterranean Programme (WWF-MedPO) on 28 April 2011. A formal agreement of collaboration for research activities to be developed under the GBYP and particularly on tagging was established with the Hopkins Marine Station of the Stanford University on 15 May 2013. GBYP, in these first five phases, continued to work constantly on a diffused network of contacts, always trying to extend and improve it as much as possible, within the rules currently existing. This activity helped the Programme to get donations and practical supports (as it was recommended by the Commission at the beginning of the programme[10]), which sometimes were destined for a precise activity.

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[10] See: ICCAT Biennial Report 2008-2009, part II (2009), Vol. 1 (COM), page 226, point 7, and ICCAT Biennial Report 2008-2009, part II (2009), Vol. 2 (SCRS), page 224, third paragraph.

Here following is the list of donors to GBYP, in alphabetic order:

- ✓ Aquastudio Research Institute, donation in kind of 1 miniPAT, estimated value 3,500 euro (2014).
- ✓ Asociación de Pesca, Comercio y Consumo Responsable de Atún Rojo (SP): Euro 6,000.00 (for GBYP in Phase 1).
- ✓ Association Marocaine de Madragues, donation in kinds of a social dinner in Tangier; estimated value not defined (for the Symposium on Trap Fishery).
- ✓ Carloforte Tonnare PIAMM, donation in kind of several tunas for biological sampling and tagging; estimated value not defined (Phase 4).
- ✓ COMBIOMA, University of Cagliari, donation in kind for tagging underwater and logistics in Sardinian traps; estimated value not defined (Phase 4).
- ✓ Departement de la Pêche Maritime, DPMA/DPRH, Rabat (MO), essential administrative and logistic support for tagging in Moroccan traps in Phase 2, 3, 4 and 5.
- ✓ Federcoopesca, Roma, donation in kind, providing 5 extra days of a purse-seiner time for tagging; estimated value not defined (Phase 4, 2013) and donation in kind of the electronic and conventional tagging activity in Phase 5 (estimated value to be defined).
- ✓ Fromentin Jean-Marc, Ph.D., IFREMER: a collection of tuna trap data from 1525 to 2000, estimated value not defined (for Data Recovery and Data Mining, Phase 4).
- ✓ Grup Balfegó (SP), donation in kinds of tuna heads prepared for sampling otoliths; estimated value: Euro 300,00 (for the GBYP Operational Meeting on Biological Sampling in Phase 2).
- ✓ Grupo Ricardo Fuentes e Hijos S.A. (SP): Euro 10,000.00 (for the Symposium on Trap Fishery in Phase 2) and the practical support for tagging in Moroccan traps in Phase 2, 3, 4 and 5.
- ✓ Hopkins Marine Station of the Stanford University, donation in kind of 7 acoustic tags and 8 miniPATs analysis and logistics in Morocco; estimated value not defined (Phase 4, 2013 and 2014).
- ✓ Institute National de Recherche Haulieutique (INRH), Tangier (MO), donation in kinds of logistic support and staff assistance for tagging in Morocco: estimated value to be defined (for GBYP Tagging in Phase 2, 3, and 4).
- ✓ Instituto Español de Oceanografia, Fuengirola, donation in kinds of staff assistance for tagging in Morocco: estimated value not defined (for GBYP Tagging in Phase 2).
- ✓ Lutcavage Molly, Ph.D.,Scool of Environment, University of Massachusetts (USA), donation of data from 697 e-tags; estimated value not defined (for GBYP Modelling in Phase 6).
- ✓ Maromadraba SARL and Es Sahel (Fuentes Group), donation in kind of divers working time, vessels support and sailors, for tagging in Morocco; estimated value: Euro 6,000.00 (for GBYP Tagging in Phase 2, 3, 4 and 5).
- ✓ Mielgo Bregazzi Roberto (SP), donation in kinds of many thousands of individual tuna data from auctions, estimated value: 50,000.00 Euros (for GBYP Data Recovery in Phase 2) and 300,000 Euros (for GBYP Data Recovery in Phase 3).

- ✓ National Research Institute for Far Seas Fisheries, Shimizu (JP), donation of many hundreds bluefin tuna samples from the central Atlantic fishery: estimated value not defined (for GBYP biological and genetic analyses in Phase 2, 3, 4 and 5).
- ✓ Oceanis srl, donation in kind for tagging underwater and logistics in Maltese cages and Sardinian traps; estimated value not defined (Phase 4).
- ✓ UNIMAR, Rome (IT), donation of data sets from 9 e-tags (for GBYP Modelling in Phase 5).
- ✓ WWF Mediterranean Programme (WWF MedPO), donation in kinds of 24 miniPATs, analysis and logistics in Morocco; estimated value: Euro 80,400.00 (for GBYP Tagging in Phase 2 and 3). Donation in kind of 6 miniPATs and 2 experimental e-tags; estimated value 40,000 euro (for tagging in the Strait of Messina in Phase 6)
- ✓ GBYP Coordinator, donation of many thousands of old catch data; estimated value not defined (Phases 3, 4 and 5).

The list does not include other entities which provided complimentary tagging activities for conventional tags.

12. GBYP web page

The ICCAT GBYP web page, which was created in the last part of Phase 1, is usually regularly updated with all documents produced by GBYP; in some cases, due to the huge workload, some set of documents are posted all together. Documents are posted only after their revision and the final approval. The texts of the GBYP pages were revised, improved and updated on February 2017.

The ICCAT Secretariat provided all the necessary support for the ICCAT GBYP web pages.

Annex 1. List of reports and scientific papers in GBYP Phase 6

Annex 1a. List of deliverables produced within the framework of GBYP contracts and activities in Phase 6 (interim reports and software products will not be included in the final copies and they are marked in yellow; technical interim reports and draft final reports are not listed; interim reports cannot be published): Volume 1

1. BFT Data Preparatory Meeting – 29 July 2016, Report of the 2016 ICCAT Bluefin Data Preparatory Meeting, Anon: 1-60
2. Coordination – August 2016: Second Review of the ICCAT Atlantic-Wide Research Programme on Bluefin Tuna , Final report, provided as SCRS/2016/192, MRAG: 1-122
3. Coordination - 31 July 2016: ICCAT GBYP Steering Committee Meeting, Report, 1-25.
4. Data recovery –20 May 2016: Short-term contract for the data recovery plan (ICCAT/GBYP 02/2016), Short report #1. Marta Gonzales Herrera:1-3
5. Data recovery – 08 July 2016: Short-term contract for the data recovery plan (ICCAT/GBYP 02/2016), Final report. Marta Gonzales Herrera:1-8
6. Data recovery –29 May 2016: Short-term contract for the data recovery plan (ICCAT/GBYP 02/2016), Short report. Necton: 1
7. Data recovery –20 August 2016: Short-term contract for the data recovery plan (ICCAT/GBYP 02/2016), Final report. Necton: 1-3
8. Data recovery – 22 August 2016: Short-term contract for the data recovery plan (ICCAT/GBYP 02/2016), Final report, Ricerca Mare Pesca: 1-3
9. Data recovery – 25 September 2016: Short term contract for the data recovery programme – Electronic tag data recovery (ICCAT GBYP 04/2016), Final report. Stanford University Hopkins Marine Station: 1-17
10. Data recovery – 22 November 2016, Short term contract for the BFT trade, market and auction data analysis (ICCAT GBYP 10/2016) – Inception report – MRAG Ltd: 1-19
11. Data recovery – January 2017, Short term contract for the BFT trade, market and auction data analysis (ICCAT GBYP 10/2016) – Final report – MRAG Ltd: 1-56
12. Data recovery – 7 February 2017, Short term contract for the data recovery plan (ICCAT GBYP 13/2016), Final report, Judit Vidal Bonavila: 1-10
13. Data recovery – September 2016, Report on programme IMROP-ICCAT/GBYP, Report, IMROP: 1-16
14. Data recovery – 13-14 July 2016- Programme de collecte de données et d'informations sur le thon rouge en Mauritanie, Training course, List of participants, 1-2
15. Biological studies – 4 August 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-1), Preliminary report #1. Taxon: 1-5
16. Biological studies – 26 September 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-1), Preliminary report #2. Taxon: 1-8

17. Biological studies – 4 November 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-1), Preliminary report #3. Taxon: 1-10
18. Biological studies – 24 February 2017: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-1), Final report. Taxon: 1-57
19. Biological studies – 30 August 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-2), Short report #1, AquaBioTech Ltd.:1
20. Biological studies – 19 September 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-2), Short report #2, AquaBioTech Ltd.:1
21. Biological studies – 15 December 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-2), Short report #3, AquaBioTech Ltd.:1
22. Biological studies – 02 March 2017: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-2), Final report, AquaBioTech Ltd.:1-9
23. Biological studies – 11 August 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-3), Short report #1, Balfego & Balfego:1-2
24. Biological studies – 16 September 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-3), Short report #2, Balfego & Balfego:1-3
25. Biological studies – 13 December 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-3), Short report #3, Balfego & Balfego:1-2
26. Biological studies – 14 February 2016: Short-term contract for biological studies – Sampling for adults (ICCAT/GBYP 07/2016-3), Final report, Balfego & Balfego:1-3
27. Biological studies – 7 November 2016 :Short-term contract for biological studies (ICCAT GBYP 09/2016), Short report #1-3, AZTI-Técnalia: 1-9
28. Biological studies – 16 February 2017 :Short-term contract for biological studies (ICCAT GBYP 09/2016), Final report, AZTI-Tecnalia: 1-101
29. Biological studies – 14 September 2016: Report of the ICCAT GBYP Workshop on bluefin tuna larval studies and surveys, provided as SCRS/2016/206, Anon: 1-20
30. Modelling approaches – 12 July 2016. Short-term contract for support to BFT assessment (ICCAT GBYP 06/2016), Progress report, Tom Carruthers: 1-6
31. Modelling approaches – 20 February 2017. Short-term contract for support to BFT assessment (ICCAT GBYP 06/2016), Final report, Tom Carruthers: 1-13
32. Modelling approaches – August 2016. Simulation Testing A Multi-Stock Model With Age-Based Movement, provided as SCRS/2016/144, Report. Tom Carruthers: 1-9

Volume 2

33. Modelling approaches – August 2016. Issues Arising From The Preliminary Conditioning Of Operating Models For Atlantic Bluefin Tuna, provided as SCRS/2016/145, Report. Tom Carruthers: 1-9
34. Modelling approaches – 10 January 2017., ABTMSE Software Design Specifications v2.1.0, Tom Carruthers: 1-7
35. Modelling approaches – 6 January 2017., M3 Software Design Specifications V1.3, Tom Carruthers: 1-6

36. Modelling approaches – 6 January 2017., Modifiable Multistock Model (M3) Users Guide V1.3, Tom Carruthers: 1-16
37. Modelling approaches – February 2017, Calculating population-wide spatial and seasonal relative abundance indices for Atlantic bluefin tuna for use in operational modelling, provided as SCRS/2017/019, report. Tom Carruthers: 1-11
38. Modelling approaches – 4-5 November 2016, ICCAT GBYP Core Modelling and MSE Group, Third meeting, report from the meeting, Anon: 1-8
39. Modelling approaches – 6-10 February 2017, Capacity building for modelling approaches – Virtual Population Analysis (VPA): Theory and application to Atlantic bluefin tuna, Training course, Agenda, 1-3
40. Modelling approaches – 6-10 February 2017, Capacity building for modelling approaches – Virtual Population Analysis (VPA): Theory and application to Atlantic bluefin tuna, Training course, List of participants, 1-2
41. Tagging – 1 August 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 03/2016 Task C), Final report. COMBIOMA: 1-28
42. Tagging – 15 July 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 03/2016 Area B), Final report. INRH: 1-29
43. Tagging – 17 June 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 03/2016 Area A), Short report #1, Istanbul University and Unimar: 1-3
44. Tagging – 30 June 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 03/2016 Area A), Short report #2, Istanbul University and Unimar: 1-5
45. Tagging – 29 July 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 03/2016 Area A), Final report, Istanbul University and Unimar: 1-24
46. Tagging – 23 August 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 08/2016, Area B), Short report. Tunipex: 1-17
47. Tagging – 20 September 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 08/2016, Area B), Final report. Tunipex: 1-21
48. Tagging – 14 August 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 08/2016, Area A), Short report #1. Unimar: 1-2
49. Tagging – 20 September 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 08/2016, Area A), Short report #2. Unimar: 1-2
50. Tagging – 31 December 2016. Short term contract for the Tagging programme 2016 (ICCAT/GBYP 08/2016, Area A), Final report. Unimar: 1-22
51. Tagging – February 2017, Short term contract for reprocessing of satellite pop up tag data, Final report, CLS: 1-220
52. Tagging CKMR– 8 February 2017, Continuation of the short term contract for the advice on Close-Kin Mark Recapture for estimating abundance of eastern Atlantic bluefin tuna: a scoping study, Updated final report, CSIRO: 1-34

53. Tagging CKMR– 15 February 2017, Continuation of the short term contract for the advice on Close-Kin Mark Recapture for estimating abundance of eastern Atlantic bluefin tuna: Genotyping issues for CKMR on Atlantic bluefin tuna, CSIRO: 1-19

54. Tag Awareness Campaign – 20 February 2017: All videos on YouTube https://www.youtube.com/channel/UCK25VrRxTajo-7I0AQbNQxw/videos?shelf_id=0&view=0&sort=dd (screenshot).

Annex 1b. List of Scientific Papers – Phase 6 (Documents marked in yellow were not included in the final copies and comprise: 1. Deliverables that were presented as scientific documents and which have already been included in the Annex 1a; 2. Internal presentations with restricted circulation (Doc. No. #38 and #40)

Volume 1

1) Brophy, D., Arrizabalaga, H., Fraile, I., Haynes, P., Kitakado, T., Hanke, A., 2016, Comparative Analysis of Individual Origin Assignments for Bluefin Tuna Sampled Within GBYP. SCRS/2016/128
2) Quelle, P., Rodriguez-Marin, E., Ruiz, M., Gatt, M., Arrizabalaga, H., 2016, Age-Length Keys Availability For Atlantic Bluefin Tuna Captured in The Eastern Management Area. SCRS/2016/133
3) Rodriguez-Marin, E., Quelle, P., Ruiz, M., Busawon, D., Golet, W., Dalton, A., Hanke, A., 2016. Updated Comparison of Age Estimates from Paired Calcified Structures From Atlantic Bluefin Tuna. SCRS/2016/134
4) Hanke, A., Guénette, S., Lauretta, M., 2016, A Summary of Bluefin Tuna Electronic and Conventional Tagging Data, SCRS 2016/135
5) Tensek, S., Di Natale A., Pagá García, A., 2016, ICCAT GBYP PSAT Tagging: The First Five Years. SCRS/2016/138
6) Pagá García, A., Palma, C., Di Natale, A., Tensek, S., Parrilla, A., De Bruyn, P., 2016, Report on Revised Trap Data Recovered by ICCAT GBYP Between Phase 1 To Phase 6. SCRS/2016/139
7) Di Natale, A., Tensek, S., Celona, A., Garibaldi, F., Oray, I., Pagá García, A., Quilez Badía, G., Valastro, M., 2016, A Peculiar Situation for YOY of Bluefin Tuna (*Thunnus thynnus*) In the Mediterranen Sea in 2015. SCRS/2016/140
8) Di Natale, A., Tensek, S., Pagá García, A., 2016, Studies on Eastern Atlantic Bluefin Tuna (*Thunnus thynnus*) Maturity – Review Of Old Literature. SCRS/2016/141
9) Di Natale, A., Bonhommeau, S., De Bruyn, P., Die, D., Melvin, G.D., Mielgo Bregazzi, R., Pagá García, A., Palma, C., Porch, C., Takeuchi, Y., Tensek, S., 2016, Bluefin Tuna Weight Frequencies From Selected Market And Auction Data Recovered By GBYP. SCRS/2016/142
10) Di Natale, A., Pagá García, A., Tensek, S., 2016, Bluefin Tuna (*Thunnus thynnus*) Growth and Displacements Derived from Conventional Tags Data. SCRS/2016/143
11) Carruthers, T., Kell, L., 2016, Simulation Testing A Multi-Stock Model With Age-Based Movement. SCRS/2016/144
12) Carruthers, T., Kell, L., 2016, Issues Arising From The Preliminary Conditioning Of Operating Models For Atlantic Bluefin Tuna. SCRS/2016/145
13) Di Natale, A., Pagá García, A., Tensek, S., 2016, Overview of the Bluefin Tuna Data Recovery in GBYP Phase 6. SCRS/2016/150
14) Cort, J.L., Estruch, V.D., 2016, Analysis of the Length–Weight Relationships for the Atlantic Bluefin Tuna, *Thunnus thynnus* (L.). SCRS/2016/154
15) Di Natale, A., 2016, Scientific Needs for a Better Understanding of the Atlantic Bluefin Tuna (*Thunnus thynnus*) Spawning Areas Using Larval Surveys. SCRS/2016/176

16) Sissenwine, M., Pearce, J., 2016. Second review of the ICCAT Atlantic-wide research programme on bluefin tuna (ICCAT GBYP Phase 6-2016). SCRS/2016/192
17) Di Natale, A., Tensek, S., Pagá García, A., ICCAT Atlantic-wide research programme for bluefin tuna (GBYP) activity report for the last part of Phase 5 and the first part of Phase 6 (2015-2016). SCRS/2016/193
18) Carruthers, T., Kell, L., 2016. Beyond MSE: Opportunities in the application of the Atlantic bluefin tuna operating models. SCRS/2016/204
19) Carruthers, T., 2016. Imputing stock-of-origin for electronic tags using stock-specific movements. SCRS/2016/205
20) Anon, 2016. Report of the ICCAT GBYP Workshop on bluefin tuna larval studies and surveys. SCRS/2016/206
21) Polacheck, T., Melvin, G., Porch, C., 2016. Some thoughts of the future of the GBYP. SCRS/2016/211
22) Apostolaki, P., Pearce, J., Barbari, A., Beddington, J., 2017, Alternative Catch Estimates From Market and Third Party Data. SCRS/2017/013
23) Carruthers, T., 2017, Calculating population-wide spatial and seasonal relative abundance indices for Atlantic bluefin tuna for use in operational modelling. SCRS/2017/019

Volume 2

24) Fraile, I., Arrizabalaga, H., Kimoto, A., Itoh, T., Abid, N., Rodriguez-Marín, E., Rooker, J., 2017, Estimating the contribution of Atlantic bluefin tuna subpopulations in the north Atlantic ocean over the last 6 years. SCRS/026/2017
25) Rodríguez-Ezpeleta, N., Díaz-Arce, N., Addis, P., Abid, N., Alemany, F., Deguara, S., Fraile, I., Franks, J., Hanke, A., Itoh, T., Karakulak, S., Kimoto, A., Lauretta, M., Lino, P.G., Lutcavage, M., Macías, D., Ngom, Sow, F., Notestad, L., Oray, I., Pascual, P., Quattro, J., Richardson, D.D., Rooker, J.R., Valastro, M., Varela, J.L., Walter, J., Irigoien, X., Arrizabalaga, H., 2017, Genetic assignment of Atlantic bluefin tuna feeding aggregations to spawning grounds. SCRS/2017/027.
26) Brophy, D., Duncan, R., Hickey, A., Abid, N.; Addis, P., Allman, R., Walter III J.F., Coelho, R., Deguara, S., Rodriguez Ezpeleta, N., Fraile, I., Karakulak, S., Arrizabalaga, H., 2017, Integrated analysis for Atlantic bluefin tuna origin assignment. SCRS/2017/028
27) Vidal Bonavila, J., 2017, Las Almadrabas de Corona de Aragon en los Siglos XVI y XVII. SCRS/2017/031
28) Di Natale, A., 2017, Tentative recovery of historical bluefin tuna catches in the Black Sea: the Bulgarian catches 1950-1971.SCRS/2017/039.
29) Di Natale, A., Tensek, S., Celona, A., Garibaldi, F., Macias Lopez, D.A., Oray, I., Ortega García, A., Pagá García, A., Potoschi, A., Tinti, F., 2017, Another Peculiar Situation For YOY Of Bluefin Tuna (Thunnus thynnus) In The Mediterranean Sea In 2016. SCRS/2017/040.
30) Di Natale, A., Tensek, S., Pagá García, A., 2017, The Disappearance of Young-Of-The-Year Bluefin Tuna from the Mediterranean Coast in 2016: Is It an Effect of the Climate Change? SCRS/2017/041.

31) Tensek, S., Pagá García, A., Di Natale, A., 2017, ICCAT GBYP Tagging Activities In Phase 6. SCRS/2017/042.
32) Pagá García, A., Di Natale, A., Tensek, S., 2017, Historical and Recent Data of Sicilian Traps: The Complexity of Data Recovery and Interpretation. SCRS/2017/043.
33) Galuardi, B., Cadrin, S.X., Arregi, I., Arrizabalaga, H., Di Natale, A., Brown, C., Lauretta, M., Lutcavage, M., 2017, Atlantic Bluefin Tuna Area Transition Matrices Estimated From Electronic Tagging and SatTagSim. SCRS/2017/045.
34) García, A., 2016, Bluefin Larval Research Highlights and Milestones: Results from the TUNIBAL Years and Its Consequent Collaborative Projects. SCRS/P/2016/029
35) Laiz-Carrión R., Uriarte A., Quintanilla J.M., García, A., 2016, Comparative trophic Ecology of Larvae of Atlantic bluefin Tuna (*Thunnus thynnus*) from NW Mediterranean and Gulf of Mexico spawning areas: the ECOLATUN project. SCRS/P/2016/030
36) Laiz-Carrión R., Uriarte A., Quintanilla J.M., García, A., 2016, Using bluefin tuna eggs and pre-flexion larvae as an estimate of maternal stable isotopes. SCRS/P/2016/031
37) Rodríguez-Ezpeleta, N., Díaz-Arce, N., Alemany, F., Deguara, S., Franks, J., Rooker, J.R., Lutcavage, M., Quattro, J., Oray, I., Macías, D., Valastro, M., Irigoien, X., Arrizabalaga, H., 2016, A Genetic Traceability Tool For Differentiation Of Atlantic Bluefin Tuna (*Thunnus thynnus*) Spawning Grounds, SCRS/P/2016/032
38) Galuardi, B., Cadrin, S.X., Arregui, I., Arrizabalaga, H., Di Natale, A., Brown, C., Lam, C.H., Lutcavage, M., 2016, Using SatTagSim To Provide Transition Matrices For Movement Inclusive Models. SCRS/P/2016/033
39) Di Natale, A., Tensek, S., Pagá García, A., 2016, Review progress made by the GBYP and Phase 6 programme. SCRS/P/2016/039
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Annex 2. GBYP contracts issued in Phase 6[11].

ICCAT-GBYP CONTRACTS (PHASE 6)								
ICCAT GBYP COORDINATION								
PHASE	YEAR	CALL FOR TENDERS or ACTIVITY	RETAINED PROPOSAL	main contact	working schedule		COST €	NOTES
					initial date	final date		
6	2016-2017	01/2016	*Second review of the ICCAT GBYP* - MRAG Ltd. - United Kingdom	John Pearce, e-mail: j.pearce@mrag.co.uk	27/04/2016	30/07/2016	49.950,00 €	
		direct contract	*ICCAT GBYP Steering Committee external member* - Ph.D. Tom Polacheck	Tom Polacheck, e-mail: runningtide.tom@gmail.com	31/07/2016	20/02/2017	17.000,00 €	2.000 € for travel
ICCAT GBYP DATA RECOVERY								
PHASE	YEAR	CALL FOR TENDERS or ACTIVITY	RETAINED PROPOSAL	main contact	working schedule		COST €	NOTES
					initial date	final date		
6	2016-2017	02/2016	*Data recovery plan* - Ph.D. Marta Gonzales Herrera - Spain	Marta Gonzales Herrera, email: martaglezher@gmail.com	27/04/2016	08/07/2016	7.500,00 €	
		02/2016	*Data recovery plan* - Necton Soc.Coop. A r.l. - Italy	Antonio Celona, e-mail: info@necton.it	30/05/2016	08/07/2016	17.100,00 €	
		02/2016	*Data recovery plan* - Ricerca Mare Pesca s.c.a.r.l. - Italy	Marcello Bascone, e-mail: marcellobascone@libero.it	18/05/2016	08/07/2016	12.610,00 €	contracted for 18.280,00 €
		13/2016	*Data recovery plan* - Ph.D. Judit Vidal Bonavila - Spain	Judit Vidal Bonavila, e-mail: juditvb88@gmail.com	12/12/2016	17/02/2016	8.000,00 €	
		04/2016	*Electronic tag data recovery* -Board of Trustees of the Leland Stanford Junior University - USA	Barbara A. Block, e-mail: bblock@stanford.edu	15/07/2016	31/08/2016	50.000,00 €	
		10/2016	*BFT Trade, market & auction data analyses* - MRAG Ltd - United Kingdom	John Pearce, e-mail: j.pearce@mrag.co.uk	04/10/2016	31/01/2017	27.475,00 €	
		MOU	*BFT data recovery in Mauritania, including training* - l'Institut Mauritanien de Recherches Océanographiques et des Pêches (IMROP) - Mauritania	Beyahe Meisse, e-mail: beyahem@yahoo.fr	12/07/2016	22/09/2016	10.000,00 €	
ICCAT GBYP TAGGING PROGRAMME								
PHASE	YEAR	CALL FOR TENDERS or ACTIVITY	RETAINED PROPOSAL	main contact	working schedule		COST €	NOTES
					initial date	final date		
6	2016-2017	03/2016	*Tagging programme (Area A)* - The Faculty of Fisheries, University of Istanbul - Turkey and Unimar Soc.Coop. - Italy	Saadet Karakulak, e-mail: karakul@istanbul.edu.tr; Adriano Mariani, e-mail: a.mariani@unimar.it	30/05/2016	31/07/2016	133.166,75 €	contracted for 140.425,00 €
		03/2016	*Tagging programme (Area B)* - Institut National de Recherche Halieutique - Morocco, as leader of consortium including one more Moroccan institution and one Spanish institution	Nouredinne Abid, E-mail: noureddine.abid65@gmail.com	30/06/2016	31/07/2016	116.125,00 €	
		03/2016	*Tagging programme (Area C)* - Centro di Competenza Sulla Biodiversita Marina- Italy, as leader of Consortium including one more Italian institution	Piero Addis, e-mail: addisp@unica.it	30/05/2016	31/07/2016	55.000,00 €	
		08/2016	*Tagging programme (Area A)* - Unimar Soc.Coop - Italy	Adriano Mariani, e-mail: a.mariani@unimar.it	15/07/2016	31/12/2016	71.046,77 €	contracted for 77.655,00 €
		08/2016	*Tagging programme (Area B)* - Tunipex S.A. - Portugal, as leader of consortium including one more Portuguese institution	Alfredo Poço, e-mail:E-mail: alfredo@tunipex.eu	01/08/2016	31/12/2016	27.500,00 €	
		05/2016	*Tag awareness activities* - Malvalanda SL - Spain	María del Puy Alvarado Landa, e-mail: tamara@malvalanda.com	23/06/2016	23/09/2016	66.070,00 €	contracted for 63.000,00 €
		continuation of the contract	*Advice on close-kin genetic tagging study* - The Commonwealth Scientific and Industrial Research Organisation (CSIRO) - Australia	Robin Thomson, e-mail: Robin.Thomson@csiro.au	23/12/2016	16/02/2017	36.500,00 €	original cost 50.000,00 AU$
ICCAT GBYP BIOLOGICAL SAMPLING AND ANALYSES								
PHASE	YEAR	CALL FOR TENDERS or ACTIVITY	RETAINED PROPOSAL	main contact	working schedule		COST €	NOTES
					initial date	final date		
6	2016-2017	07/2016	*Sampling for BFT adults* - AquaBioTech Ltd - Malta, as the leader of consortium including three more Maltese institution	Simeon Deguara, e-mail:dsd@aquabt.com	01/08/2016	17/02/2017	96.162,00 €	
		07/2016	*Sampling for BFT adults* - Balfegó & Balfegó S.L. - Spain	Begonya Mèlich Bonancia, e-mail: bmelich@grupbalfego.com	01/08/2016	10/02/2017	34.898,00 €	
		07/2016	*Sampling for BFT adults* - Taxon Estudios Ambientales S.L. - Spain, as a leader of consortium including one more Spanish institution	Antonio Belmonte Ríos, e-mail: antonio.belmonte@taxon.es	15/07/2016	10/02/2017	41.100,00 €	
		09/2016	*Biological studies* - Fundación AZTI - Spain, as leader of a Consortium including 13 more institutions (1 Spain, 4 Italy, 1 Malta, 1 Ireland, 1 Turkey, 1 Portugal, 1 Morocco (w/o budget), 1 France (w/o budget), 1 Japan (w/o budget), 1 USA (w/o budget) (+ 6 subcontracts: 1 Croatia, 1 France, 1 Italy, 1 Spain, 1 Turkey and 1 USA)	Haritz Arrizabalaga, e-mail: harri@azti.es	23/09/2016	16/02/2017	404.683,00 €	
		cost reimbursement	*ICCAT GBYP Workshop on bluefin tuna larval studies and surveys (Madrid, Spain)*	Antonio Di Natale, e-mail: antonio.dinatale@iccat.int	12/09/2016	14/09/2016	5.526,01 €	
ICCAT GBYP MODELLING APPROACHES								
PHASE	YEAR	CALL FOR TENDERS or ACTIVITY	RETAINED PROPOSAL	main contact	working schedule		COST €	NOTES
					initial date	final date		
6	2016-2017	06/2016	*Modelling Approaches: Support to Bluefin Tuna Stock Assessment* - The University of British Columbia - Canada	Thomas Robert Carruthers, e-mail: t.carruthers@fisheries.ubc.ca	30/05/2016	21/02/2017	120.000,00 €	original cost 116.820 USD + travels
		cost reimbursement	*ICCAT GBYP Core Modelling Group Meeting (Madrid, Spain)*	Antonio Di Natale, e-mail: antonio.dinatale@iccat.int	04/11/2016	05/11/2016	13.926,36 €	
		cost reimbursement	*ICCAT GBYP short training course on VPA for Atlantic bluefin tuna (Miami, USA)*	Antonio Di Natale, e-mail: antonio.dinatale@iccat.int	06/02/2017	10/02/2017	39.772,57 €	call for tenders 12/2016
		cost reimbursement	*External expert assistance for DPM and assessment - Ph.D.* Abdelouahead Ben Mhamed - Morocco	Abdelouahed Ben Mhamed, e-mail: a.benmahamed@mail.com	04/11/2016	05/11/2016	2.219,00 €	

[11] The final amount of some contracts is still provisional, because the administrative procedures were not finalised when this scientific report was prepared.

Annex 3. List of meetings and activities attended by GBYP coordination staff in Phase 6

No.	date	place	Meeting or activity	Motivation
1	15/03/2016	Madrid (SP)	Meeting with CLS for discussing the methodology for assessing the data derived from e-tags	Detailed explanations about the methodology for elaborating the e-tags data and the various algorithms.
2	12-14/07/2016	Nouadhibou (Mauritania)	Training course for BFT Data Recovery	Enhancement of the local capacity in terms of BFT data recovery
3	25-29/07/2016	Madrid (SP)	Bluefin Species Group Intersessional Meeting	Presentation of GBYP data and analyses
4	30-31/07/2016	Madrid (SP)	GBYP Steering Committee Meeting	Review of Phase 6 activities and plans for GBYP Phase 7
5	8-11/09/2016	Isla Cristina (SP)	2016 (XVI) Meeting of Tuna Trap Captains	Report about the existing and potential bluefin tuna spawning areas for the eastern stock (nop)
6	12-14/09/2016	Madrid (SP)	ICCAT GBYP Workshop on bluefin larval studies and surveys	Discussions about the possibilities provided by larval studies for detecting trends
7	26-30/09/2016	Madrid (SP)	SCRS BFT Species Group	Overview of the GBYP activities, other BFT subjects
8	3-7/10/2016	Madrid (SP)	SCRS Plenary	Overview of the GBYP activities.
9	1-3/11/2016	Madrid (SP)	Tuna RFMOs MSE Meeting	Presentation of the GBYP MSE work
10	4-5/11/2016	Madrid (SP)	ICCAT GBYP Core Modelling MSE Group meeting	Review of the advances and programme for the last part of GBYP Phase 6 and for Phase 7.

NOTE: nop = non official participation; the meeting was attended on personal behalf and without costs for the programme.