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POTENTIAL FURTHER CONSIDERATIONS ON THE CONDITIONING OF OPERATING MODELS OF ATLANTIC BLUEFIN TUNA

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SUMMARY

ICCAT BFTWG completed the stock assessment using multiple stock assessment methods in 2017, and they are going to proceed with the MSE process: development of MP in 2018. It is well recognized that the performance results of MPs often depend on the design of the OM and its conditioning that capture the range of potential population dynamics. It is therefore critical to consider them carefully before moving to the development of MP, but this has been a monumental task given the complexity of ABFT. The ICCAT GBYP Core modelling group has developed the OM by incorporating the mixing between two stocks, and the trial specifications. However, the 2017 stock assessment raised a number of issues that may require further consideration for the OMs, particularly related to time varying catchability and selectivity, effective sample sizes for composition data and stock mixing dynamics that are limited information. Overall, we commend the work of the ICCAT GBYP Core modeling group for producing the current OM and framework for evaluating MPs. Our purpose in this document is not to criticize this work but to foster clarification and further discussion about key uncertainties that have emerged during the 2017 assessment.

RÉSUMÉ

Le groupe d'espèces sur le thon rouge de l'ICCAT a réalisé une évaluation des stocks au moyen de plusieurs méthodes d'évaluation des stocks en 2017 et va s'atteler à poursuivre le processus de la MSE, en développant des procédures de gestion (MP) en 2018. C'est un fait bien établi que les résultats du rendement des MP dépendent souvent de la conception du modèle opérationnel et de son conditionnement qui reflète la gamme des dynamiques potentielles de la population. Il est dès lors essentiel de les prendre soigneusement en considération avant de passer au développement de procédures de gestion, mais il s'agit d'une tâche colossale compte tenu de la complexité du thon rouge de l'Atlantique. Le groupe de pilotage de modélisation du GBYP a mis au point le modèle opérationnel en incorporant le mélange entre les deux stocks et les spécifications de la mise à l'essai. Néanmoins, l'évaluation du stock de 2017 a donné lieu à un grand nombre de questions pouvant faire l'objet d'un examen plus approfondi pour les modèles opérationnels, notamment en ce qui concerne la capturabilité et la sélectivité variant dans le temps, la taille effective de l'échantillonnage pour les données sur la composition et la dynamique du mélange des stocks comptant des informations lacunaires. De manière générale, nous félicitons le travail réalisé par le groupe de pilotage de modélisation du GBYP d'avoir produit le modèle opérationnel actuel et le cadre d'évaluation des modèles opérationnels. L'objectif du présent document ne consiste pas à critiquer ce travail, mais d'encourager la clarification et d'approfondir la discussion concernant les principales incertitudes ayant surgi pendant l'évaluation de 2017.

RESUMEN

El Grupo de especies de atún rojo de ICCAT completó la evaluación de stock en 2017 utilizando varios métodos de evaluación de stock y va a iniciar el proceso MSE: desarrollo de un procedimiento de ordenación (MP) en 2018. Está ampliamente reconocido que los resultados del desempeño de los MP dependen a menudo del diseño de los OM y de su condicionamiento que capta la gama de la dinámica potencial de la población. Por lo tanto, es crítico considerarlos detenidamente antes de pasar al desarrollo de los MP, pero esto ha supuesto una tarea monumental dada la complejidad del atún rojo del este. Grupo de modelación del GBYP ha desarrollado el OM incorporando la mezcla entre los dos stocks, y las especificaciones de prueba.

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Sin embargo, la evaluación de stock de 2017 planteó una serie de cuestiones que podrían requerir una consideración adicional para los OM, sobre todo en lo concierne a la capturabilidad y selectividad variables; el tamaño efectivo de la muestra para los datos de composición y la dinámica de mezcla del stock que tengan información limitada. En general, elogiamos los trabajos del grupo de modelación de ICCAT para producir el OM actual y el marco para evaluar los MP. La finalidad de este documento no es criticar este trabajo, sino impulsar aclaraciones y debates adicionales sobre incertidumbres clave que salieron a la luz en la evaluación de 2017.

KEYWORDS

Bluefin tuna, conditioning, operating model, uncertainty, management procedure, MSE

Introduction / Background

ICCAT Atlantic Bluefin tuna Working Group (BFTWG) completed the stock assessment using multiple stock assessment methods in 2017, and is proceeding with the MSE process in 2018 (SCRS, 2017). In the new recommendation for West Atlantic bluefin tuna in 2017 [Rec. 17-06], the managers clearly included the plan about MSE in the paragraphs from 14 to 16. ICCAT GBYP core modelling group has developed an operating model (OM) for Atlantic bluefin tuna expressing their unique biology and fisheries. The BFTWG is scheduled to start developing a management plan (MP) in 2018 using the customized OM for Atlantic bluefin tuna.

Atlantic bluefin tuna is well known to have two stocks (west and east) in the Atlantic, and they are mixed in the high seas, outside their spawning grounds; Gulf of Mexico (west origin) and Mediterranean (east origin). ICCAT GBYP core modelling group tried to incorporate this uniqueness into the OM and "conditioning", i.e. fitting to data, is crucial for the OM to reflect actual stock behavior appropriately. However, the mixing information with the stock origin unfortunately is very limited, and the catch statistics as well as their size structure contain huge uncertainties especially in the 1990s and the 2000s in the Mediterranean before the introduction of the strict management regulations in 2008. Based on the experience of the BFTWG with the VPA2Box model incorporating mixing, it is very difficult to incorporate mixing in stock assessment models. The results are very sensitive to the mixing hypothesis and/or data. Thus, their biological uniqueness and the quantity and the quality of data warrant utmost caution for the conditioning of the OM.

As the performance results of MPs often depend on the design of the OM and its conditioning, it is important to capture the range of potential population dynamics. It is therefore critical to consider them carefully before moving to the development of MP. The GBYP core modelling group showed a trial specification for the OM conditioning in three major uncertainty axes: recruitment, current abundance, and natural mortality/maturity (in combination), and in total 36 reference sets were proposed. However, the 2017 stock assessment raised a number of issues that may require further consideration for the OMs, particularly related to time varying catchability and selectivity, effective sample sizes for composition data and stock mixing dynamics. Furthermore, given the complexity of the OMs for ABFT, there are a number of clarifications that may be requested for complete understanding.

The MSE process has been introduced in a number of t-RFMOs for several tuna species. They generally have considered a very large number of OM reference sets, even for stocks without migrations (**Table 1**). Given the complexity of the OM for Atlantic bluefin tuna, probably more uncertainties should be accounted for in addition to the trial specifications suggested by the GBYP core modelling group. In this document, we provide some additional thoughts to be considered regarding what kind of uncertainty may need to be further discussed for the conditioning of the OM, in large part based on the experience of the 2017 assessment. We also list some points of clarification which can be addressed. We suggest the issues raised here regarding conditioning be reviewed by the BFTWG. This document was developed based on Carruthers and Kell (2017, SCRS/2016/145) and on the Annex 4 in the report by the GBYP core modelling group held in September 2017.

Discussion and further considerations

Overall, we commend the work of the ICCAT GBYP Core modeling group for producing the current OM and framework for evaluating MPs. This has been monumental task given the complexity of ABFT. Our purpose in this document is not to criticize this work but to foster clarification and further discussion about key uncertainties that have emerged during the 2017 assessment.

Our questions and issues to be discussed (see more details for supplemental information):

1. [BRP] What are the assumed starting conditions (B1/B0) of the OMs in 1983 and at the start of the model time period 1950? How is this derived and how is B0 derived for each OM? How does MP performance depend critically upon starting conditions in 1983 and stock status at the start of the projection period? This is particularly important in setting the target level for empirical MPs based on indices.
2. [BRP] Does starting in 1983 allow the scenarios to adequately account for the high/low stock recruitment uncertainty debate adequately? For instance, the WBFT recruitment specifications may not consider the 'high' recruitment scenario as any Beverton-Holt relationship starting in 1983-present would not entertain high recruitments estimated in the 1970s or earlier. Furthermore, it is not clear what steepness is for the Beverton-Holt 'estimated' steepness but it appears higher than what has generally been seen for the 'High' recruitment scenario.
3. [BRP] Does the 1983 starting point for the age-structured part of the assessment essentially mean that very few HCRs or MPs that require estimating productivity could get biological reference points with data from 1983-2015, given that the biomass trajectories are mostly one-way trips and given the long-term changes in productivity we seem to have seen in the stock? Can model-based MP work on these dynamics?
4. [Size] Time varying selectivity and catchability were key issues in the 2017 assessment. How does the model deal with these issues, particularly related to use of indices as empirical MPs?
    a) Does the Beta parameter that accounts for the non-linearity term for catchability account for non-linearity?
    b) How do we address time-varying selectivity?
    c) How does the model address the issue of what appears to be selection for a specific cohort?
5. [Size] How does the model deal with the effective sample size issues related to the composition data? How would we give a model-based MP the kind of length/age composition that we actually see from the fisheries?
6. [Catch] Given the uncertainty around the total removals for EBFT, should these be considered part of the range of OMs?
7. [Mixing] How does the model fit to the microchemistry data? Mixing information is limited to the recent years, and inter-annual variability has been recognized (**Figure 1**). Does the model implicitly allow for time-varying mixing? Our suggestion for alternative option is to use directly the actual values for the years with data and apply its average for the rest of years.
8. [Mixing] How were the percentage of mixing in the overlapped zone in the confidence ellipses calculated (**Figure 2**)?
9. [Mixing] Are the pop-up satellite tag and arrival tagging data for movement of stocks sensitive to the boundaries in the area stratification? Our suggestion for alternative option is to combine some areas or to change slightly the line of the boundary by the support of those tagging data.
10. [ALK] Does the model implicitly allow for time-varying Age-length-key (ALK)? The ALK is also limited to the recent years, and the authors showed its time-variability. Our suggestions for alternative options are a) to use directly the actual values for the years with data and apply its average for the rest of years, and b) to apply a single ALK for both stocks with all data in the east and the west to cover all size ranges.
11. [CPUE] Does the master index adequately represent the true stock? The BFTWG was not to combine data to produce indices for the multi-national pelagic longline index for western Atlantic bluefin tuna after 2 inter-sessional small meetings, and suggested individual CPCs may, bi-laterally decide to combine datasets to create joint indices. Japanese longline standardized indices already exist may be alternative option.
12. [CPUE] How would we use an assessment model based MP with such a short CPUE time series? Can we trust the behavior of series with 5-10 years of observations.
13. [CPUE] Can we consider the data up to 2017 in the OM? The most updated abundance index of larval survey in GOM showed extremely high value in 30 years.
14. [CPUE] Several indices were not used to condition the OM, can they be used for MPs?
15. [MP] How would/could we consider MPs that are totally different such as close-kin estimators.
16. [MP] How do we adequately account for the issues of time-varying catch ability and selectivity in the indices?

Lessons learned in the CCSBT

- MP, Meta-rule, and robustness test have to be developed parallelly.
- It is important to make a check-list for the conditioning of the OM, because once we start to focus on developing MPs, we can easily miss problems in the OM. For example, the estimated stock size in OM by year/sub-year/area, to check if the OM hit boundaries what we subjectively decided.

- For the development of the MP, from the experiences of CCSBT (the aerial survey was canceled that is a part of current MP and they have to make new MP in 2018), they recommended to use indices that are likely to continue in the future.

Supplemental information for our questions:

- [Items 4-5: Size] The official ICCAT task 2 size data should be used with the quality control by the Secretariat (Ortiz and Palma, 2017 was used for SS3 in 2017).

- [Items 4-5: Size] It should be re-recognized that the model is based on the generally poor size data (**Tables 2 and 3**), especially for the purse sein in the Mediterranean that has been the largest component of the total catch and that French purse seine data, that we relied on for the size assumption for the other purse sein, are based on the average weight of each set.

  Tables 2 and 3 show roughly how much size data are collected to their catch with the percentage[5] and its corresponded color[6] (reddish colors show poor or no size and greenish colors show good size coverage), and how large the catch by fleet is in a year with the bar[7].

- [Items 4-5: Size] Time-varying catch ability and selectivity

  It is recognized that the length composition data by Ortiz and Palma (2017) showed some time-varying trends. In the 2017 stock assessment, it was frequently discussed if there is time-varying catchability and/or selectivity, which are not considered in the current OM. These items also need to be addressed in parallel be considered with the current fixed assumptions.

  In the 2017 assessment one of the most challenging aspects for fitting the stock synthesis model was fitting to the length composition data. Fits were particularly difficult because of the time-varying selectivity seen for the PS-FR-SP and the very peaked nature of the length composition for the Japan LL (**Figure 3**). In the Western SS model, the Japan longline selectivity was modeled as time-varying. The time varying nature of selectivity for the PS fleet has substantial impact on the presumed size/age composition of the greatest source of removals. Secondly the JLL selectivity (**Figure 4**), if indeed time varying, has implications for the interpretation of this index.

- [Items 7-9: Mixing] Movement of stock by Pop-up satellite and archival tagging data, from only known stock origin (MED or GOM) in **Table 2.2** in the specification document (**Table 4**) should be checked by biologists, if there are any strange pattern, or if they are realistic. The data is mostly available for the western origin fish, and there are not many movements for eastern origin fish to the Western Atlantic that may not match to the microchemistry data.

- [Items 7-9: Mixing] The rest of pop-up and archival data (no MED or GOM) could be used as the supplemental information to help the previous questions.

- [Items 15-16: MP] Regarding empirical index-based MPs, two issues loomed large over the 2017 assessment, both time varying catchability potentially linked to environmental, regulatory or other fishing practice change and time-varying selectivity. These issues occupied much of analysts' time in attempting to model these processes to fit the historical data. If we are to entertain index-based MPs, how do we adequately account for these issues in the indices?

[5] The total measured weight by year and fleet was divided by the total weight, and the percentage is shown in Tables 2 and 3. The total weight of the measured fish by year and fleet was roughly obtained by multiplying the number of fish and the converted the average length into weight in each length bin (the ranges of length are 30-350cm and 10-350cm with 5cm bin for the west and the east, respectively) by L-W relationship (Rodriguez *et al.,* 2015).

[6] The colors in Tables 2 and 3 correspond to this percentage. There are 9 categories: No size, $0<p<5$, $5\leq p<10$, $10\leq p<25$, $25\leq p<50$, $50\leq p<75$, $75\leq p<90$, $90\leq p<105$, $105\leq p$ with red, red pink, pink, light orange, light yellow, light yellow green, yellow green, green and dark green, respectively.

[7] The bar shows the percentage of catch by fleet in a year.

References

Carruthers T. and L. Kell. 2017. Issues arising from the preliminary conditioning of operating models for Atlantic bluefin tuna Collect. Vol. Sci. Pap. ICCAT, 73(6): 2171-2182.

ICCAT. 2017a. Report of the 6th Meeting, ICCAT GBYP Core Modelling group, Madrid, Spain, 25 and 26 September 2017, ANNEX 4: Specifications for MSE trials for Bluefin tuna in the North Atlantic.

ICCAT. 2017b. Recommendation 17-06 Recommendation by ICCAT for an interim conservation and management plan of Western Atlantic Bluefin tuna.

ICCAT. 2017c. Report of the 2017 Bluefin tuna stock assessment meeting. Madrid, Spain.

Ortiz M., and Palma C. 2017. Review and analysis of size frequency samples of Bluefin tuna SCRS/2017/166.

Merino G., Kell L.T., Arrizabalaga H., Santiago J., Sharma R., Ortiz de Zarate V., and De Bruyn P. 2017. Updated Evaluation of Harvest Control Rules for North Atlantic albacore through Management Strategy Evaluation. SCRS/2017/093.

Mosqueira, Iago. 2017. Management Strategy Evaluation for the Indian Ocean Tuna Albacore Stock. IOTC-2017-WPM08-13.

IOTC. 2017b. Update on Yellowfin Tuna Management Procedure Evaluation Oct 2017. IOTC-2017-WPM08-17.

IOTC. 2017c. Report of the 8th Working Party on Methods. IOTC-2017-WPM08-R

Walter, J.F, Lauretta M, Kimoto A, Hanke A., K Ramirez and G. Melvin. 2017. Report of the working group on multi-national pelagic longline index for western Atlantic bluefin tuna. Collect. Vol. Sci. Pap. ICCAT, 74(6): 2784-2808.

Table 1. Conditioning considered for other species.

tRFMOs	Species	Number of scenarios	Parameter	References
CCSBT	SBT	432	M_0,M_{10},steepness, ω,CPUE,CPUE ages, ψ	CCSBT-OMMP/1706/04
ICCAT	ALB	132	M, steepness, Model scenarios	SCRS/2017/093
IOTC	ALB	1440	M, sigmaR, steepness, CPUE_cv, ESS, LLq,LLsel	IOTC–2017–WPM08–13
IOTC	YFT	216	M, steepness, Tag lambdas, Tag Mixing Period, CPUE bias, CPUE	IOTC–2017–WPM08–17
IOTC	BET	108	M, steepness, Tag lambdas, Tag Mixing Period, CPUE bias, CPUE	IOTC–2017–WPM08–17
IOTC	SWO	1728*	M, steepness, sigmaR, growth, ESS, CPUE scaling, CPUE, Catchability increase	IOTC–2017–WPM08–R

*proposed

Table 2. Availability of size data for WBFT.

Year	JPLL	USA_CAN_PSFS	USA_CAN_PSFB	USA_TRAP	USA_CAN_HPN	USA_RRFB	USA_RRFS	OTHER_ATL_LL	CAN_HL	GOM_LL_USMEX	JPLL_GOM	CAN_TRAP	CAN_GSL
1950		No	No	No	No	No	No					No	No
1951		No	No	No	No	No	No					No	No
1952				No	No	No		No				No	No
1953				[illegible]	No	No	No	No					No
1954		No	No	o	No	No	No	No					No
1955				%	No	No	No	No					No
1956				%	No	No	No	No					No
1957	No				No	No	No	No					No
1958	No	No	No	[illegible]	No	No	No	No					
1959	No	No	No	25%	No	No	No	No				No	No
1960	No	No	No	28%	No	No	No	No				No	No
1961	No	No	No	6006%	No	No	No	No				No	No
1962	No	No	No	No	No	No	No	No				No	No
1963	No	No	No	No	No	No	No	No				No	No
1964	o	No	No	No	No	No	No	No				No	No
1965	o	No	No	No	No	No	No	No				No	No
1966	No	No	No	No	No	No	No	No				No	No
1967	No	No	No	No	No	No	No	No				No	No
1968	No	No	No	No	No	No	No	No				No	No
1969	No	No		No	No	No	No	No				No	No
1970	No	lo	No	No	No	No	No	No				No	No
1971	2%	No	No	No	No	No	No	No				No	No
1972	1%	No	No	No	No	0%	No	No		No		No	No
1973	0%	No	No	No	No	3%	No	No		No		No	No
1974	0%	No	No	No	No	No	No	No		No	No	No	12%
1975	3%	No	No			No	No	No		No	20%	17%	24%
1976	13%	No	No		No	No	No	No		No	31%	47%	35%
1977	16%	2%	No		No	No	No	No		No	26%	13%	22%
1978	10%	3%	10%		No	No	No	No		No	40%	77%	16%
1979	17%	3%	18%		No	1%	23%	No		No	25%	19%	18%
1980	14%	No	No		No	No	No	No		No	25%	63%	14%
1981	7%	2%	No		No	No	No	No		No	10%	72%	2%
1982	19%	No	No		No	4%	9%	No		No		78%	23%
1983	30%	1%	103%		45%	47%	10%	55%		No		76%	64%
1984	44%	4%	39%		61%	78%	24%	22%		37%		221%	50%
1985	98%		90%		77%	88%	7%	29%		29%		47%	No
1986	82%		91%		94%	71%	8%	6%		13%			No
1987	51%		96%		94%	51%	3%	26%		19%		No	No
1988	58%		95%		70%	55%	5%	52%	No	21%		No	
1989	30%		90%		72%	66%	6%	28%	88%	16%		No	
1990	9%		94%		67%	84%	2%	16%	87%	11%		No	
1991	11%		81%		43%	83%	1%	2%	80%	17%			
1992	26%		85%		33%	91%	2%	5%	86%	16%		No	
1993	19%		89%		47%	58%	5%	24%	87%	No		84%	
1994	19%		91%		56%	53%	6%	37%	89%	8%		88%	
1995	2%		98%		54%	54%	2%	30%	84%	10%		87%	
1996	20%		92%		69%	81%	4%	18%	85%	59%		88%	
1997	15%		101%		75%	64%	12%	27%	87%	No		91%	
1998	15%		101%		70%	66%	8%	28%	88%	17%		93%	
1999	15%		104%		67%	73%	14%	9%	101%	8%		102%	
2000	8%		101%		31%	66%	10%	3%	95%	63%		103%	
2001	1%		105%		62%	57%	55%	10%	96%	64%		100%	
2002	6%		97%		77%	57%	15%	16%	100%	141%		100%	
2003	19%		197%		115%	104%	No	14%	101%	87%		84%	
2004	10%		110%		76%	63%	29%	27%	101%	20%		100%	
2005	13%		104%		71%	66%	4%	34%	101%	24%		101%	
2006	11%		No		74%	2%	2%	20%	100%	16%		104%	
2007	10%		78%		93%	45%	2%	50%	99%	15%		No	
2008	65%				62%	63%	9%	23%	88%	11%		44%	
2009	94%		226%		177%	68%	6%	89%	114%	20%		92%	
2010	93%				85%	57%	7%	38%	83%	35%		96%	
2011	96%				104%	107%	4%	39%	89%	66%		94%	
2012	93%		115%		99%	106%	2%	43%	88%	66%		96%	
2013	93%		108%		104%	117%	3%	50%	87%	83%		97%	
2014	92%		100%		103%	103%	3%	68%	89%	84%		91%	
2015	91%		115%		108%	106%	2%	89%	99%	105%		103%	

Table 3. Availability of size data for EBFT.

Year	SPA_BB	SPAFRA_BB	JPLL_MED	JPLL_NEA1	JPLL_NEA2	LL_OTH	PS_NOR	PS_HRV	PS_FRASPA	PS_OTH	PS_Inflated	SPAMOR_TRP	MORPOR_TRP	TRP_OTH	OTHER
1950	No						No			No		o		No	No
1951	No						0%			No		No		No	No
1952	No						%			No		No		No	2%
1953	2%						18%			No		No		No	1%
1954	No						6%			No		No		No	3%
1955	No						27%			No		No		No	4%
1956	14%						65%			No		%		1%	6%
1957	2%		51%				70%			No		%		0%	23%
1958	1%		No				96%			No		%		0%	5%
1959	3%		No				104%			No		0%		0%	1%
1960	6%		No				104%			No		No		1%	8%
1961	5%		No			No	01%			No		1%		1%	3%
1962	5%		No				05%			No		No		1%	No
1963	3%		No			No	106%			No		1%		1%	No
1964	3%		No			No	96%			No		1%		1%	No
1965	2%		No			No	96%			No		No		2%	No
1966	7%		No			No	99%		No	No		No		1%	No
1967	1%		No			No	100%		No	No		No		0%	No
1968	14%		No			No	99%		No	No		No		2%	No
1969	No		No			No	74%		No	No		No		1%	No
1970	No		No			No	60%		105%	No		No		2%	No
1971	1%		11%			No	89%		79%	No		No		1%	No
1972	No		No			No	23%		11%	No		No		2%	3%
1973	0%		No			No	17%		64%	No		No		2%	1%
1974	0%		No			No	95%		28%	No		No		1%	1%
1975	No		14%			No	106%		25%	%		No		11%	1%
1976	2%		15%			No	118%		44%			No		9%	No
1977	3%		12%			No	75%		19%	4%		No		6%	No
1978	3%		No			No	86%		59%	3%		No		6%	0%
1979	No		11%			No	161%		21%	No		No		5%	No
1980	3%		17%			No	91%		21%			No		7%	0%
1981	1%		26%			No	105%		34%	%		No		5%	No
1982	5%		1%			No	No		61%	9%		No		4%	6%
1983	No		12%			0%	No		19%	No		2%		1%	0%
1984	2%		10%			14%	170%		47%	11%		8%		1%	6%
1985	2%		38%			No			58%	No		10%		No	2%
1986	1%		26%			No	No		62%	o		No		No	6%
1987	0%		23%			6%			72%	No		No		No	5%
1988	No		21%			7%			47%	No		No		No	1%
1989	1%		29%			No			60%	No		No		No	1%
1990	0%		30%	2%		1%			75%	No		No		18%	0%
1991	17%		8%	5%		1%		No	122%	2%		No		13%	0%
1992	3%		24%	2%		1%		No	7%	3%		56%		10%	12%
1993	1%		9%	3%		2%		No	25%	No		71%		29%	10%
1994	1%		4%	8%		0%		No	81%	4%		No		12%	2%
1995	0%		4%	5%		9%		No	80%	3%		59%		17%	14%
1996	1%		7%	4%		9%		No	37%	2%		60%		8%	7%
1997	0%		5%	7%		15%		No	49%	1%		63%		7%	10%
1998	3%		8%	5%		30%		No	29%	No	No	No		11%	2%
1999	7%		5%	2%		7%	No	No	33%	0%	No	No		17%	3%
2000	77%		1%	3%		30%		No	37%	1%	No	46%		55%	33%
2001	14%		6%	0%		13%		No	38%	0%	No	No		26%	14%
2002	15%		1%	9%		24%		0%	30%	2%	No	No		31%	20%
2003	No		4%	9%		27%		No	35%	0%	No	No		85%	34%
2004	No		0%	13%		23%		18%	33%	11%	No	No		77%	39%
2005	8%		5%	7%		23%		29%	41%	10%	No	15%		107%	2%
2006	10%		4%	5%		31%		11%	54%	23%	No	2%		64%	1%
2007		8%	8%	8%		40%		18%	53%	14%		2%		165%	5%
2008		15%	64%	91%		35%		62%	48%	3%		13%		144%	3%
2009		23%	135%	94%		61%		15%	111%	9%		42%		75%	15%
2010		20%	No		95%	49%		152%	135%	56%		33%		29%	27%
2011		27%			94%	26%		28%	280%	76%		35%		58%	30%
2012		20%			93%	35%		No	182%	%			26%	38%	51%
2013		51%			93%	32%		No	103%	3%			27%	12%	24%
2014		83%			93%	25%		14%	29%	9%			25%	1%	20%
2015		4%			92%	15%		23%	31%	3%			26%	12%	23%

Table 4. The stock movement data in the specification document

Table 2.2. The recorded quarterly transitions for electronic tags of NOAA, DFO, WWF, AZTI, UNIMAR, IEO, UCA, FEDERCOOPESCA, COMBIOMA, GBYP of known stock of origin (i.e. those tags entering either the Gulf of Mexico or the Mediterranean). For example, there are 20 tags that at some point entered the Gulf of Mexico (Western fish) that exhibited a movement from the Gulf of St Laurence to the Western Atlantic.

TO AREA:

		Eastern										Western									
	FROM AREA:	GOM	CAR	WATL	GSL	SCATL	NCATL	NEATL	EATL	SEATL	MED	GOM	CAR	WATL	GSL	SCATL	NCATL	NEATL	EATL	SEATL	MED
Jan-Mar	GOM											12	1	1							
	CAR											2		2							
	WATL			1								3	2	13			2		2	2	
	GSL																				
	SCATL																			1	
	NCATL																			1	
	NEATL																				
	EATL								1	1	1								1		
	SEATL									3	1			1					2	2	
	MED										17										
Apr-Jun	GOM											1		10	1						
	CAR																				
	WATL									1				5	2		2		3		
	GSL																				
	SCATL																				
	NCATL													2			2		1		
	NEATL																				
	EATL									1				2					5		
	SEATL								1	1	1			2			1		2		
	MED							3	2	2	1				1						
Jul-Sept	GOM																				
	CAR																				
	WATL											1		39	2						
	GSL											3		20	1						
	SCATL																				
	NCATL																1				
	NEATL						1	1													
	EATL								2	1							1	3	4		
	SEATL									2	1										
	MED									2	1										
Oct-Dec	GOM											4	1								
	CAR																				
	WATL											14	7	49		1			1	2	
	GSL											1		1							
	SCATL																				
	NCATL																		1	1	
	NEATL													1			1			1	
	EATL									1				1						2	
	SEATL								3	3	1										
	MED									3	1										

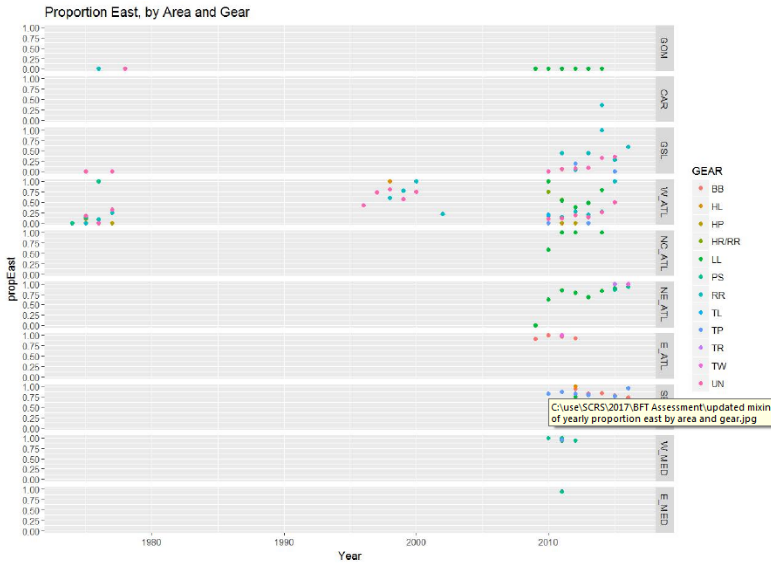

Figure 10. Estimated annual eastern proportions by area and gear from the ICCAT Stock Composition Database indicating proportion eastern origin.

Figure 1. Estimated annual eastern proportion from the GBYP microchemistry analyses (ICCAT 2017c).

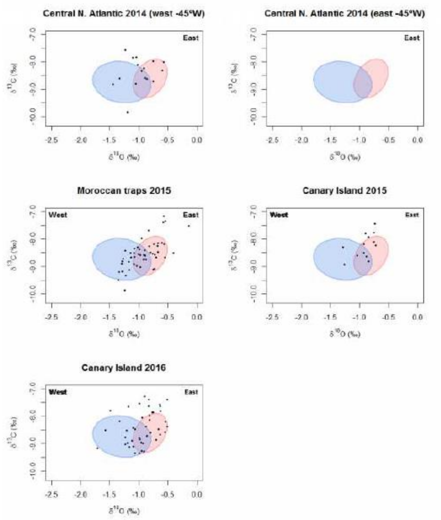

Figure 4.2: Confidence ellipses (1 SD or ca. 68% of sample) for otolith δ13C and δ18O values of yearling bluefin tuna from the east (red) and west (blue) along with the isotopic values (black dots) for otolith cores of bluefin tuna collected from central North Atlantic (west of 45°W), central North Atlantic (east of 45°W), Moroccan traps and Canary Islands.

Figure 2. Confidence ellipses (1 SD or ca. 68% of sample) for otolith δ13C and δ18O values of yearling bluefin tuna from the east (red) and west (blue) along with the isotopic values (black dots) for otolith cores of bluefin. (ICCAT 2017d).

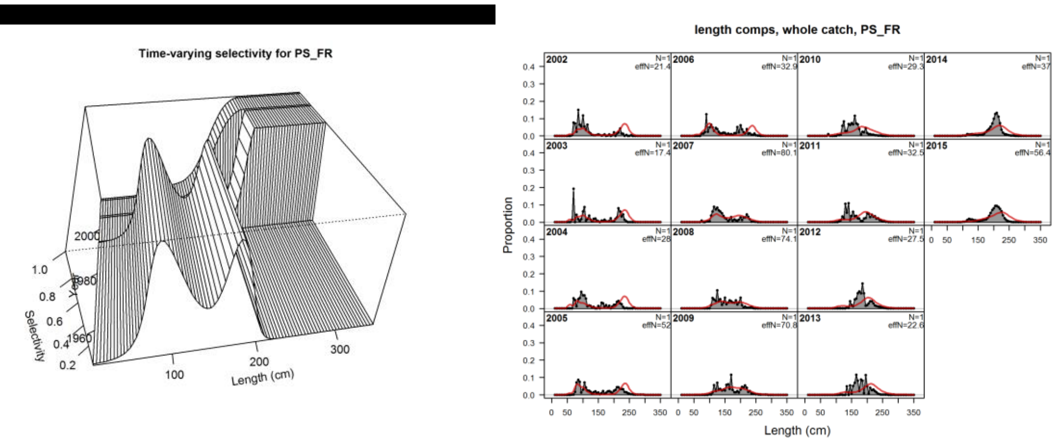

Figure 3. Time varying selectivity for PS-FR-SP and fits to length composition, indicating the difficulty of fitting to the fleet with the largest removals.

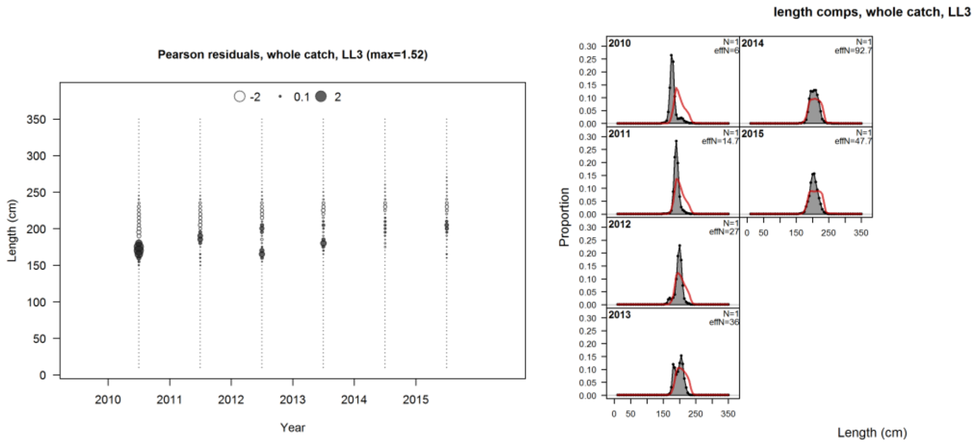

Figure 4. Pearson residuals for Japan LL (time period 2) and fits to length composition showing the very peaked distribution indicative of potentially time-varying or cohort-specific selectivity.