

REVIEW OF BEHAVIOR OF INDIVIDUAL OPERATING MODELS FROM BFT MSE REFERENCE GRID

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SUMMARY

We reviewed the behavior of individual OMs from BFT MSE for further consideration and finalization of OM reference grid. Some notable behaviors such as very large west-east stock size difference and seasonal movement which are different from current perception were observed over a range of OMs and BFT WG needs to consider how to treat them in OM plausibility/weighting discussion.

RÉSUMÉ

Nous avons examiné le comportement des OM individuels de la MSE du thon rouge aux fins d'un examen plus approfondi et la finalisation de la grille de référence des OM. Certains comportements notables, tels que la très grande différence de taille des stocks d'ouest-est et le déplacement saisonnier, qui sont différents de la perception actuelle, ont été observés dans une série de OM et le Groupe d'espèces sur le thon rouge doit examiner comment les traiter dans la discussion sur la plausibilité/la pondération des OM.

RESUMEN

Se ha revisado el comportamiento de cada uno de los OM de la MSE para el atún rojo para una ulterior consideración y finalización de la matriz de referencia de los OM. Algunos comportamientos notables como la gran diferencia de tamaño de stock oeste-este y el movimiento estacional, que son diferentes de la percepción actual, se observaron en una serie de OM y el Grupo de especies de atún rojo necesita considerar cómo tratarlos en la discusión de plausibilidad/ponderación de OM.

KEYWORDS

Atlantic bluefin tuna, conditioning, management strategy evaluation, operating model, plausibility

Introduction

Management strategy evaluation (MSE) is widely considered to be the most appropriate way to evaluate the trade-offs achieved by alternative management strategies and to assess the consequences of uncertainty for achieving management goals (Punt et al. 2014). The MSE for Atlantic bluefin tuna (ABT) is now under the development by SCRS (anon. 2019). The management procedure (MP) involves assessing the consequences of alternative options for management actions, for example determination of total allowable catch (TAC) (Rademeyer et al. 2007). Under MSE, MPs are evaluated for its performance on models which simulate the dynamics of a stock, which are called Operating Models (OMs). OMs are fundamental to MSE as it is the playing field for evaluating multiple candidate MPs, thus it is essential to construct a group OMs (OM reference grid) which collectively cover the plausible range of reality reasonably well.

Defining such a group of OMs to be used for the evaluation of candidate MPs while ensuring reasonable fit to data across every OM are called conditioning. Conditioning of reference grid of OMs for ABT MSE was conducted by trying to fit the model to various sources of data. However, after multiple trials, it was found that the available data did not permit reliable estimation of the bluefin tuna abundance scales in the West and East areas, and that there are conflicts amongst the different data that inform on mixing (anon. 2020(1)). Therefore, in order to overcome the issue, BFT MSE Technical Group held in February 2020 came up with a solution by specifying mixing and scale values at certain levels on further uncertainty axes being added to the grid. In addition, BFT MSE Technical Group also agreed to add another uncertainty axis on weighting of length frequency data. As a result, the OM

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interim grid now consists of 96 OMs, 64 of which are conditioned to the data. The current OM interim uncertainty grid is as **Table 1** (anon. 2020(1)). The OM fitting results of individual models are available here (<https://drive.google.com/drive/folders/1s9gAnWx9wKXiAmmVqZZuZeuMIXW2aUVf>).

Due to time constraint caused by for the most part COVID-19 pandemic but also by the need to conducting stock assessment of ABT, BFT WG in July 2020 or any other group never had a chance to go through the results of individual model fitting of the latest grid in detail which became available in May 2020. However, in order to advance the long waited MSE for ABT, BFT WG is now moving further towards the adoption of reference OMs. For doing so, though OM re-conditioning and further discussion on the appropriateness of the current uncertainty grid is not excluded, MSE Technical Group in September 2020 recommended to move to plausibility weighting discussion using survey among BFT WG participants (anon. 2020(2)). After the initial plausibility weighting through survey, the MSE Technical Group further recommended that the BFT WG determine if there are OMs that are (a) exhibit particularly implausible behavior and (b) are not sufficiently weighted in the first round (anon. 2020(2)).

Based on the backdrop, this document attempts to review the behavior of individual models of the current interim OM reference grid (May 4, 2020 version) mainly by eye-ball inspection in order to provide information for further discussion to determine if there is any OM “that exhibits particularly implausible behavior” and for the finalization of the OM reference grid for BFT MSE.

Materials and Methods

The individual output of 64 OMs of May 4, 2020 version was studied if any concerning characteristics can be observed. The basic point of view to look at the OM output is if dynamics of an OM may cause concern to stakeholders on the appropriateness or plausibility of the particular OM. Specifically, we mainly looked at biomass information (absolute biomass, east/west difference, recruitment) as well as trend, movement and mixing. For doing so, we noted several long-standing perceptions of BFT; Western stock is roughly about 10% of eastern stock; Adult BFT moves into spawning area in the spawning season; BFT stocks are recovering, or at least not declining, in recent years. Of course, those perceptions are not necessarily based on data and could be inaccurate. That is specifically why OMs for MSE need to cover a range of uncertainty which goes beyond the perception. However, in order for MSE to be widely accepted by stakeholders, OM behavior should look reasonable to the perception of stakeholders.

Results

The features that can be found widely among OMs are summarized in **Table 2**. The summary of MSY reference point information is provided in **Table 3**. The detailed analysis of individual OMs are presented in **Table 4**.

In general the current interim grid OMs provide much larger size difference between eastern and western stocks than perceived 10:1 which is close to assumed ratio of population scale by area in uncertainty grid (Fig 5 and Table 3 of individual OM reports). Of course, the perception that west/east is 10% is for area biomass rather than stock size and also based on uncertain modeling results. However, current western stock biomass is 3.8 % of that of east stock on average among 64 OMs and in 13 OMs it is less than 1%, providing a stark difference between the two stocks' size. They are basically from OMs with recruitment scenario 1 (regime shift). Many of these OMs also exhibit in east very high current biomass (as high as over 1 million ton), very high B0 (as high as over 3 million ton), very high recruitment (higher than historically observed in assessment) and/or higher predicted probability of eastern stock than observed in almost of the areas and age classes (Fig 14b in individual report) . This naturally results in that very high (50-80%) portion of west area biomass is eastern stock. During the test trials of candidate MPs, interestingly it was found that these OMs were relatively easy to conserve the western stock (results not shown).

Another widely shared feature over many OMs is low spawning migration / concentration of eastern stock biomass in south Atlantic Ocean (SATL), especially for age class 3 (age 9+) (Fig 12 of individual OM reports). Concentration of eastern stock in SATL has been a concerning feature of the BFT OM. In the current OMs too, basically in all OMs eastern stock gathers most in SATL. In some OMs (those with XX in **Table 2**), about 80% of eastern stock stays in EATL all the time. It has been of concern of the OM because the model may be creating “cryptic biomass” to let escape biomass in an area where no fishing is occurring. As EATL in OM include Gibraltar where fishing activity is occurring, the area is not necessary without fishing but still if the level of concentration of eastern stock in EATL is plausible or not may need to be further discussed. Further, in about half of OMs this biomass concentration in EATL coincides with low migration of eastern stock to spawning area in spawning season; here, we mean “low spawning migration” as that only about 20-30% of eastern stock is observed in MED in April – June. This apparent lack of spawning migration in eastern stock may cause concern among stakeholders about the plausibility of these OMs.

The third peculiar behavior of OMs, which was not so widely shared as the previous two, was a recent steep declining trend of west area biomass. We observed this behavior in 8 OMs (**Table 2**), with Recruitment scenario “2” (no regime shift), west biomass “+”, and length composition weight “L”. As west area biomass is influenced by the level of inflow of eastern stock to west area, this decrease was caused by the decreasing trend of the fraction of eastern biomass in the west area (Fig 16 of individual OM reports). However, no indices show the sign of such declining trend of biomass in recent years. In addition, this large fluctuation and trend in fraction of eastern biomass in the west area itself is of some question because OMs are specified for the level of average fraction of a stock in the opposite area. Why there is a large trend in the fraction in the opposite area may need to be further investigated. In the test trial of candidate MPs, these OMs proved to be difficult to conserve western stock (results not shown).

In addition, though no specific calculation was made, we note that the change of R_0 in regime shift scenarios (Recruitment “1” and “3”) is remarkable; basically in all regime shift scenarios, R_0 in the late period (1988-2016) is roughly 4 times or more larger than that of the early period. The questions we need to consider when weighing OMs are how plausible this level of regime shift is and its implication to Recruitment “3” OMs, where future recruitment will be reduced by at least 75%

Discussion

As stated earlier, OMs should be developed to cover plausible range of reality. That means that OMs should be allowed to have higher structural uncertainty than models used for stock assessment, while data uncertainty should be at the same level (We don’t believe this aspect has been well considered, but it is out of scope of this paper.). How much uncertainty should be allowed, however, is a difficult question to answer. Here, we provide some observation / noticeable behavior of some of the OMs in the interim grid. How these OMs should be treated in the MSE, i.e. survey weighting only, further down weight, selecting data component for fit or deleted from OM grid, warrants further discussion of WG members.

Ultimately, OMs are for evaluating candidate MPs. If those behavior described above does not affect the performance of MPs, they don’t really matter for the purpose of MSE. However, particular behavior of OMs such as very small western stock size or steep decrease of recent west area biomass may influence the conservation of the weak western stock. Movement of eastern stock may affect how BFT is caught in the projection of MSE as catch are materialized based on area. It is our view that OM behavior needs further investigation in particular in light of MP performance.

Reference

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Table 1. Factors and levels of key uncertainty axes in the reference grid of operating models.

	<i>Western stock</i>	<i>Eastern stock</i>
<i>Recruitment</i>		
1	B-H with $h=0.6$ ("high R0") switches to $h=0.9$ ("low R0") starting from 1975	50-87 B-H $h=0.98$ switches to 88+ B-H $h=0.98$, with a changed unfished recruitment level.
2	B-H with $h=0.6$ fixed, high R0	B-H with $h=0.7$ fixed, high R0
3	Historically as in Level 1. In projections, "low R0" switches back to "high R0" after 10 years	Historically as in Level 1. In projections, 88+ B-H with $h=0.98$ switches back to 50-87 B-H with $h=0.98$ after 10 years.
<i>Spawning fraction both stocks</i>		<i>Natural Mortality rate both stocks</i>
A	Younger (E+W same)	High
B	Older (E+W older but different for the 2 stocks)	Low
<i>Western stock mixing into East area (average proportion of western stock biomass in the East area over 1965-2016)</i>		
I	1%	
II	20%	
<i>Scale (average SSB by area over 1975-2016 for the West area and 1968-2016 for the East area):</i>		
	West area	East area
--	15kt	200kt
-+	15kt	400kt
+-	50kt	200kt
++	50kt	400kt
<i>Weight for log likelihood for length composition data (Low or High):</i>		
L	LHw=0.05	
H	LHw=1	

Table 2. Summary of prominent features of interim reference grid OMs. **Very high East biomass/very low west biomass** typically means that current eastern stock biomass is close to 1 million ton and western stock biomass is below 2% of that of eastern stock. **XX** in this column means that western stock is less than 1% of that of east. **High SATL biomass/little MED inflow** typically means that at least 60-80% of eastern stock always spends time in SATL and only about 20% of eastern stock enters MED during the 2nd quarter. **XX** in this column means that this tendency is severe.

	Very high East biomass/very low west biomass	High SATL biomass/little MED inflow	Strange decline of west area biomass
#1 (1 A I – L)	XX	X	
#2 (2 A I – L)			
#4 (1 B I – L)	XX	X	
#5 (2 B I – L)			
#7 (1 A II – L)	XX	X	
#8 (2 A II – L)			
#10 (1 B II – L)	X	X	
#11 (2 B II – L)			
#13 (1 A I –+ L)	XX	X	
#14 (2 A I –+ L)		X	
#16 (1 B I –+ L)	XX	X	
#17 (2 B I –+ L)		X	
#19 (1 A II –+ L)	XX	X	
#20 (2 A II –+ L)		X	
#22 (1 B II –+ L)	XX	X	
#23 (2 B II –+ L)		X	
#25 (1 A I + L)	X	X	
#26 (2 A I + L)			X
#28 (1 B I + L)		X	
#29 (2 B I + L)			X
#31 (1 A II + L)	X	X	
#32 (2 A II + L)			X
#34 (1 B II + L)		X	
#35 (2 B II + L)			X
#37 (1 A I ++ L)	X	X	
#38 (2 A I ++ L)			X
#40 (1 B I ++ L)	X	X	
#41 (2 B I ++ L)	X		X
#43 (1 A II ++ L)	X	X	
#44 (2 A II ++ L)			X
#46 (1 B II ++ L)	X	X	
#47 (2 B II ++ L)		X	X
#49 (1 A I – H)	X		
#50 (2 A I – H)		X	
#52 (1 B I – H)	XX		
#53 (2 B I – H)		X	
#55 (1 A II – H)	X		
#56 (2 A II – H)		X	
#58 (1 B II – H)	XX		
#59 (2 B II – H)		X	
#61 (1 A I –+ H)	XX		
#62 (2 A I –+ H)		X	
#64 (1 B I –+ H)	XX		
#65 (2 B I –+ H)		XX	
#67 (1 A II –+ H)	X		
#68 (2 A II –+ H)		X	
#70 (1 B II –+ H)	XX		
#71 (2 B II –+ H)		XX	

#73 (1 A I +- H)	X		
#74 (2 A I +- H)			
#76 (1 B I +- H)			
#77 (2 B I +- H)		XX	
#79 (1 A II +- H)	X		
#80 (2 A II +- H)			
#82 (1 B II +- H)			
#83 (2 B II +- H)		XX	
#85 (1 A I ++ H)	X		
#86 (2 A I ++ H)		XX	
#88 (1 B I ++ H)	X		
#89 (2 B I ++ H)		XX	
#91 (1 A II ++ H)	X		
#92 (2 A II ++ H)		X	
#94 (1 B II ++ H)	X		
#95 (2 B II ++ H)		XX	

Table 3. Summary of information related to MSY reference point. Current B = $BMSY * B_MSY$. B0 = $BMSY / (BMSY_B0)$. W/E, current B = west Current B / east current B. W/E, BMSY = west BMSY / east BMSY.

OM		MSY	FMSY	BMSY	BMSY_B0	F_FMSY	B_BMSY	Dep	Current B	B0	W/E, current B	W/E, BMSY
1	East stock	72,746	0.1000	658,660	0.2650	0.2760	1.3080	0.3470	861,527	2,485,509	0.73%	1.53%
	West stock	869	0.1710	10,674	0.2800	0.6540	0.5880	0.1650	6,276	38,121		
2	East stock	20927	0.074	323874	0.329	0.796	0.895	0.295	289,867	984,419	3.52%	7.75%
	West stock	1225	0.122	27929	0.366	1.906	0.365	0.133	10,194	76,309		
4	East stock	77612	0.078	735528	0.254	0.297	1.169	0.297	859,832	2,895,780	0.45%	2.04%
	West stock	1199	0.133	15092	0.255	0.911	0.254	0.065	3,833	59,184		
5	East stock	18254	0.057	390545	0.326	1.124	0.856	0.279	334,307	1,197,991	3.20%	7.06%
	West stock	1049	0.142	29957	0.354	2.532	0.357	0.127	10,695	84,624		
7	East stock	72217	0.099	655186	0.265	0.262	1.334	0.354	874,018	2,472,400	0.75%	1.55%
	West stock	843	0.165	10787	0.282	0.607	0.609	0.172	6,569	38,252		
8	East stock	21,362	0.0750	330,172	0.3290	0.7390	0.9680	0.3190	319,606	1,003,562	3.21%	7.56%
	West stock	1,186	0.1310	27,764	0.3660	1.8650	0.3700	0.1360	10,273	75,858		
10	East stock	67893	0.082	663376	0.254	0.624	0.912	0.232	604,999	2,611,717	1.17%	3.44%
	West stock	1933	0.11	22881	0.255	1.122	0.31	0.079	7,093	89,729		
11	East stock	19561	0.057	413497	0.326	1.004	0.894	0.292	369,666	1,268,396	3.01%	6.85%
	West stock	1073	0.143	30866	0.355	2.395	0.361	0.128	11,143	86,946		
13	East stock	78430	0.102	710333	0.264	0.21	1.659	0.438	1,178,442	2,690,655	0.54%	1.42%
	West stock	891	0.169	10804	0.283	0.672	0.593	0.168	6,407	38,177		

14	East stock	23026	0.074	361531	0.329	0.599	1.161	0.382	419,737	1,098,878	2.49%	6.89%
	West stock	1226	0.121	27725	0.366	1.669	0.377	0.138	10,452	75,751		
16	East stock	85542	0.078	820877	0.254	0.233	1.402	0.356	1,150,870	3,231,799	0.35%	1.83%
	West stock	1195	0.131	15180	0.256	0.909	0.267	0.068	4,053	59,297		
17	East stock	22869	0.06	506295	0.332	0.899	1.062	0.352	537,685	1,524,985	1.81%	5.34%
	West stock	1057	0.128	28825	0.354	2.367	0.337	0.119	9,714	81,427		
19	East stock	77,393	0.1010	705,483	0.2640	0.1920	1.6870	0.4450	1,190,150	2,672,284	0.61%	1.44%
	West stock	833	0.1610	10,863	0.2830	0.6050	0.6730	0.1900	7,311	38,385		
20	East stock	23549	0.074	371367	0.33	0.563	1.236	0.408	459,010	1,125,355	2.33%	6.60%
	West stock	1167	0.13	27129	0.365	1.618	0.394	0.144	10,689	74,326		
22	East stock	84465	0.077	821476	0.255	0.227	1.378	0.351	1,131,994	3,221,475	0.36%	1.87%
	West stock	1135	0.149	15343	0.255	0.8	0.269	0.069	4,127	60,169		
23	East stock	23097	0.059	496352	0.323	0.796	1.127	0.364	559,389	1,536,693	1.80%	5.44%
	West stock	1046	0.139	29600	0.354	2.051	0.341	0.121	10,094	83,616		
25	East stock	71889	0.101	649847	0.264	0.242	1.388	0.366	901,988	2,461,542	1.82%	1.63%
	West stock	878	0.186	11136	0.278	0.349	1.472	0.409	16,392	40,058		
26	East stock	20,825	0.0710	331,570	0.3310	0.8350	0.8750	0.2900	290,124	1,001,722	5.91%	7.80%
	West stock	1,066	0.1130	28,986	0.3710	1.5590	0.5920	0.2200	17,160	78,129		
28	East stock	76,489	0.0810	714,171	0.2500	0.4310	0.8490	0.2120	606,331	2,856,684	6.52%	3.29%
	West stock	1,743	0.1370	23,653	0.2520	0.4390	1.6710	0.4210	39,524	93,861		

29	East stock	19028	0.057	408249	0.327	1.104	0.831	0.272	339,255	1,248,468	5.55%	6.74%
	West stock	932	0.164	29949	0.356	1.893	0.629	0.224	18,838	84,126		
31	East stock	72,233	0.1010	655,242	0.2650	0.2240	1.4260	0.3780	934,375	2,472,611	1.99%	1.81%
	West stock	914	0.1870	12,374	0.2760	0.3090	1.4990	0.4140	18,549	44,833		
32	East stock	21,208	0.0720	335,451	0.3300	0.7840	0.9360	0.3090	313,982	1,016,518	5.50%	7.45%
	West stock	1,047	0.1210	28,012	0.3700	1.4370	0.6160	0.2280	17,255	75,708		
34	East stock	76040	0.081	710890	0.25	0.403	0.913	0.228	649,043	2,843,560	6.34%	3.64%
	West stock	1863	0.153	25984	0.251	0.419	1.583	0.397	41,133	103,522		
35	East stock	18,986	0.0580	400,090	0.3210	1.0640	0.8860	0.2840	354,480	1,246,386	4.56%	6.62%
	West stock	924	0.1630	29,227	0.3540	1.8330	0.5530	0.1960	16,163	82,562		
37	East stock	80,437	0.1020	727,236	0.2630	0.1780	1.7870	0.4700	1,299,571	2,765,156	1.25%	1.44%
	West stock	868	0.1800	11,146	0.2790	0.3710	1.4530	0.4060	16,195	39,950		
38	East stock	22,214	0.0690	366,279	0.3320	0.6440	1.1900	0.3950	435,872	1,103,250	4.91%	7.88%
	West stock	1,052	0.1200	32,355	0.3720	1.4940	0.6610	0.2460	21,387	86,976		
40	East stock	87013	0.077	834643	0.256	0.206	1.395	0.357	1,164,327	3,260,324	1.53%	1.92%
	West stock	1116	0.162	15771	0.252	0.413	1.13	0.285	17,821	62,583		
41	East stock	22882	0.059	494366	0.328	0.843	1.068	0.35	527,983	1,507,213	3.17%	5.93%
	West stock	1003	0.163	31845	0.356	1.706	0.525	0.187	16,719	89,452		
43	East stock	79805	0.102	724704	0.263	0.167	1.794	0.472	1,300,119	2,755,529	1.47%	1.62%
	West stock	903	0.183	12345	0.276	0.316	1.548	0.427	19,110	44,728		

44	East stock	23458	0.072	374833	0.329	0.594	1.2	0.395	449,800	1,139,310	3.85%	6.88%
	West stock	1077	0.135	28753	0.367	1.278	0.603	0.221	17,338	78,346		
46	East stock	89,779	0.0760	864,532	0.2560	0.2080	1.3990	0.3580	1,209,480	3,377,078	1.46%	1.87%
	West stock	1,081	0.1540	16,163	0.2560	0.4670	1.0930	0.2800	17,666	63,137		
47	East stock	23,735	0.0600	505,692	0.3280	0.8210	1.0980	0.3600	555,250	1,541,744	2.72%	6.03%
	West stock	1,016	0.1720	33,072	0.3560	1.8010	0.4570	0.1630	15,114	92,899		
49	East stock	69,835	0.1650	492,359	0.2390	0.1390	2.0610	0.4930	1,014,752	2,060,079	1.09%	1.88%
	West stock	970	0.1250	11,283	0.2920	0.4420	0.9780	0.2860	11,035	38,640		
50	East stock	25171	0.088	353825	0.325	0.647	1.128	0.367	399,115	1,088,692	6.07%	8.54%
	West stock	1742	0.063	33846	0.364	1.104	0.716	0.261	24,234	92,984		
52	East stock	66225	0.123	518190	0.219	0.19	1.825	0.4	945,697	2,366,164	0.97%	2.61%
	West stock	1442	0.087	15182	0.246	0.667	0.607	0.149	9,215	61,715		
53	East stock	24,560	0.0620	459,921	0.3220	0.9920	0.9430	0.3040	433,706	1,428,326	5.40%	6.79%
	West stock	1,414	0.0610	33,834	0.3490	1.4520	0.6920	0.2410	23,413	96,946		
55	East stock	68,968	0.1560	494,973	0.2420	0.1320	2.0500	0.4960	1,014,695	2,045,343	1.12%	2.06%
	West stock	958	0.1440	12,126	0.2880	0.3900	0.9410	0.2710	11,411	42,104		
56	East stock	25489	0.086	360940	0.325	0.56	1.237	0.402	446,483	1,110,585	5.71%	8.66%
	West stock	1736	0.071	34731	0.361	0.941	0.734	0.265	25,493	96,208		
58	East stock	67905	0.126	527537	0.216	0.171	1.878	0.406	990,714	2,442,301	0.83%	2.54%
	West stock	1240	0.104	15908	0.256	0.473	0.515	0.132	8,193	62,141		

59	East stock	24,646	0.0660	462,459	0.3170	0.9000	1.0460	0.3310	483,732	1,458,861	4.86%	7.50%
	West stock	1,594	0.0580	38,090	0.3480	1.4080	0.6170	0.2150	23,502	109,454		
61	East stock	81,405	0.1460	603,697	0.2500	0.1070	2.3130	0.5780	1,396,351	2,414,788	0.76%	1.60%
	West stock	1,050	0.1100	11,686	0.3020	0.5830	0.9140	0.2760	10,681	38,695		
62	East stock	30,083	0.1090	412,064	0.3190	0.4530	1.5080	0.4810	621,393	1,291,737	3.94%	7.25%
	West stock	1,831	0.0630	33,923	0.3620	1.0320	0.7220	0.2610	24,492	93,710		
64	East stock	76,675	0.1300	592,834	0.2140	0.1410	2.1990	0.4710	1,303,642	2,770,252	0.62%	2.22%
	West stock	1,456	0.0790	15,181	0.2470	0.7030	0.5340	0.1320	8,107	61,462		
65	East stock	29,096	0.0600	564,265	0.3230	0.7980	1.2270	0.3960	692,353	1,746,950	3.20%	5.70%
	West stock	1,344	0.0840	35,234	0.3540	1.7850	0.6280	0.2220	22,127	99,531		
67	East stock	77,686	0.1510	564,339	0.2440	0.1040	2.3220	0.5670	1,310,395	2,312,865	0.99%	1.91%
	West stock	1,045	0.1300	12,893	0.2920	0.3700	1.0050	0.2930	12,957	44,154		
68	East stock	30,389	0.1060	421,188	0.3190	0.4200	1.5640	0.4990	658,738	1,320,339	3.77%	7.25%
	West stock	1,739	0.0720	34,562	0.3610	0.9180	0.7190	0.2590	24,850	95,740		
70	East stock	78,004	0.1270	607,476	0.2160	0.1330	2.1840	0.4720	1,326,728	2,812,389	0.60%	2.21%
	West stock	1,245	0.1010	15,964	0.2570	0.4890	0.4990	0.1280	7,966	62,117		
71	East stock	32,642	0.0650	610,471	0.3180	0.6240	1.3100	0.4170	799,717	1,919,720	3.11%	6.16%
	West stock	1,811	0.0520	40,778	0.3450	1.2580	0.6090	0.2100	24,834	118,197		
73	East stock	65,250	0.1800	446,647	0.2250	0.1270	2.1220	0.4770	947,785	1,985,098	5.03%	4.54%
	West stock	2,261	0.1140	26,594	0.2950	0.2610	1.7920	0.5290	47,656	90,149		

74	East stock	24,856	0.0850	352,773	0.3260	0.6310	1.1020	0.3590	388,756	1,082,126	13.45%	11.35%
	West stock	2,116	0.0760	45,069	0.3670	0.6250	1.1600	0.4260	52,280	122,804		
76	East stock	65,250	0.1170	512,698	0.2230	0.2080	1.5150	0.3380	776,737	2,299,094	6.38%	4.92%
	West stock	2,128	0.1000	29,392	0.2600	0.4240	1.6850	0.4380	49,526	113,046		
77	East stock	23,454	0.0650	444,127	0.3180	0.9640	0.9650	0.3070	428,583	1,396,626	11.44%	9.25%
	West stock	1,693	0.0780	45,722	0.3540	0.9050	1.0720	0.3800	49,014	129,158		
79	East stock	68484	0.178	469994	0.225	0.113	2.251	0.507	1,057,956	2,088,862	4.04%	4.10%
	West stock	1979	0.132	24816	0.29	0.196	1.723	0.5	42,758	85,572		
80	East stock	24601	0.085	351346	0.326	0.532	1.236	0.403	434,264	1,077,748	12.47%	12.58%
	West stock	2324	0.07	49099	0.362	0.627	1.103	0.399	54,156	135,633		
82	East stock	66987	0.118	524796	0.223	0.194	1.577	0.352	827,603	2,353,345	6.33%	5.46%
	West stock	2266	0.109	33535	0.261	0.334	1.563	0.408	52,415	128,487		
83	East stock	21,919	0.0600	430,690	0.3190	0.9300	0.9650	0.3080	415,616	1,350,125	12.07%	10.70%
	West stock	1,734	0.1060	51,119	0.3540	1.1170	0.9810	0.3470	50,148	144,404		
85	East stock	79,970	0.1720	562,933	0.2290	0.0880	2.5790	0.5910	1,451,804	2,458,223	2.41%	2.73%
	West stock	1,651	0.1170	19,888	0.2960	0.2680	1.7560	0.5200	34,923	67,189		
87	East stock	29,397	0.1050	406,122	0.3210	0.4880	1.3990	0.4490	568,165	1,265,178	8.89%	9.53%
	West stock	2,108	0.0740	44,135	0.3660	0.6030	1.1440	0.4190	50,490	120,587		
88	East stock	73387	0.128	568211	0.215	0.146	2.011	0.432	1,142,672	2,642,842	4.19%	4.14%
	West stock	2052	0.101	28427	0.26	0.409	1.684	0.438	47,871	109,335		

89	East stock	31,695	0.0690	579,122	0.3170	0.6980	1.2550	0.3980	726,798	1,826,883	6.55%	7.05%
	West stock	1,871	0.0550	44,710	0.3470	0.8210	1.0650	0.3690	47,616	128,847		
91	East stock	81,185	0.1730	568,050	0.2290	0.0840	2.6060	0.5970	1,480,338	2,480,568	2.61%	3.12%
	West stock	1,749	0.1320	22,452	0.2900	0.1980	1.7180	0.4980	38,573	77,421		
92	East stock	28,928	0.1020	406,193	0.3210	0.3990	1.5610	0.5010	634,067	1,265,399	8.34%	10.51%
	West stock	2,232	0.0740	48,126	0.3620	0.5920	1.0990	0.3980	52,890	132,945		
94	East stock	76,196	0.1270	588,982	0.2160	0.1350	2.0680	0.4470	1,218,015	2,726,769	4.24%	4.54%
	West stock	2,183	0.1100	32,332	0.2610	0.3180	1.5980	0.4170	51,667	123,877		
95	East stock	26,608	0.0680	494,017	0.3150	0.7010	1.2170	0.3830	601,219	1,568,308	8.46%	9.43%
	West stock	1,760	0.1050	52,631	0.3560	1.0420	0.9660	0.3440	50,842	147,840		

Table 4. detailed description of individual OM behavior.

OM	Noticeable behavior
#1 (1 A I – L) TOT=5826	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 862 kt, B0; 2.5 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. almost always about half of biomass in SATL. - West stock: very low biomass (current B; 6 kt (0.7% of east), B0: 38 kt (1.5% of east)), about 70% of western area biomass are eastern origin.
#2 (2 A I – L) TOT=5934	<ul style="list-style-type: none"> - Strange trend in seasonal movement in eastern stock (in 1990-2010 eastern fish move to NATL in spawning season.) - Up to 80% of western area biomass are eastern origin.
#4 (1 B I – L) TOT=6220	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 860 kt, B0; 2.9 Mt). Majority of eastern fish is almost always in SATL. Up to the 90's, almost 80% of fish is always in SATL. - West stock: very low biomass (current B; 3.9 kt (0.45% of east), B0; 59 kt (2% of east)). Up to 80% of western area biomass are eastern origin.
#5 (2 B I – L) TOT=6614	<ul style="list-style-type: none"> - Up to 80% of western area biomass are eastern origin.
#7 (1 A II – L) TOT=5668	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 874 kt, B0; 2.5 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish is almost always in SATL. - West stock: very low biomass (current B; 6.5 kt (0.8% of east), B0: 38 kt (1.6% of east)), about 70-80% of western area biomass are eastern origin.
#8 (2 A II – L) TOT=5884	<ul style="list-style-type: none"> - Strange trend in seasonal movement in eastern stock (in 1990-2010 eastern fish move to NATL in spawning season.) - Up to 80% of western area biomass are eastern origin.
#10 (1 B II – L) TOT=6370	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 605 kt, B0; 2.6 Mt), Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish is almost always in SATL. - West stock: very low biomass (current B; 7.1 kt (1.2% of east), B0: 90 kt (3.4% of east)).
#11 (2 B II – L) TOT=6318	<ul style="list-style-type: none"> -
#13 (1 A I ++ L) TOT=5751	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.2 Mt, B0; 2.7 Mt). Very high recruitment recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is almost always in SATL. - West stock: very low biomass (current B; 6.4 kt (0.5% of east), B0: 38 kt (1.4% of east)).
#14 (2 A I ++ L) TOT= 5898	<ul style="list-style-type: none"> - Only about 20-30% of eastern stock in MED in Apr-Jun. Majority of eastern fish is almost always in SATL.
#16 (1 B I ++ L) TOT=6126	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.2 Mt, B0; 3.2 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is almost always in SATL. - West stock: very low biomass (current B; 4.1 kt (0.35% of east), B0: 59 kt (1.8% of east)).
#17 (2 B I ++ L) TOT=6347	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is almost always in SATL.
#19 (1 A II ++ L) TOT=5595	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.2 Mt, B0; 2.7 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is almost always in SATL. - West stock: very low biomass (current B; 7.3 kt (0.6% of east), B0: 38 kt (1.4% of east)).
#20 (2 A II ++ L) TOT=5842	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is almost always in SATL.

#22 (1 B II -- L) TOT=5972	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.1 Mt, B0; 3.2 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is almost always in SATL. - West stock: very low biomass (current B; 4.1 kt (0.36% of east), B0: 60 kt (1.9% of east)).
#23 (2 B II -- L) TOT=6303	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is almost always in SATL.
#25 (1 A I +- L) TOT=5797	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 902 kt, B0; 3.2 Mt). Very high recruitment in recent years. Only about 20-30% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times. - West stock: very low biomass relative to east (current B; 1.8% of east, B0:1.6% of east).
#26 (2 A I +- L) TOT=5871	<ul style="list-style-type: none"> - Strange trend in seasonal movement in eastern stock (in 1995-2005 eastern fish move to EATL in spawning season.)
#28 (1 B I +- L) TOT=6166	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times.
#29 (2 B I +- L) TOT=6412	<ul style="list-style-type: none"> - Strange trend in west area biomass (steep decline from the mid 2000's). This is caused by steep decline of eastern fish moving to west.
#31 (1 A II +- L) TOT=5685	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 934 kt, B0; 2.5 Mt). Very high recruitment in recent years. Only about 20-30% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times. - West stock: very low biomass relative to east (current B; 2.0% of east, B0: 1.8% of east).
#32 (2 A II +- L) TOT=5833	<ul style="list-style-type: none"> - Strange trend in west area biomass (steep decline from 2010). This is caused by steep decline of eastern fish moving to west.
#34 (1 B II +- L) TOT=6148	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times.
#35 (2 B II +- L) TOT=6377	<ul style="list-style-type: none"> - Strange trend in west area biomass (steep decline from 2010). This is caused by steep decline of eastern fish moving to west.
#37 (1 A I ++ L) TOT=5720	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.3 Mt, B0; 2.8 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times. - West stock: very low biomass relative to east (current B; 16 kt (1.3% of east), B0: 40 kt (1.4% of east)).
#38 (2 A I ++ L) TOT=5822	<ul style="list-style-type: none"> - Strange trend in west area biomass (steep decline from 2010). This is caused by steep decline of eastern fish moving to west.
#40 (1 B I ++ L) TOT=6060	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.2 Mt, B0; 3.3 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times. - West stock: very low biomass relative to east (current B; 18 kt (1.5% of east), B0: 63 kt (1.9% of east)).
#41 (2 B I ++ L) TOT=6281	<ul style="list-style-type: none"> - Strange trend in west area biomass (steep decline from 2010). This is caused by steep decline of eastern fish moving to west. - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times.
#43 (1 A II ++ L) TOT=5605	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.3 Mt, B0; 2.8 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times. - West stock: very low biomass relative to east (current B; 19 kt (1.5% of east), B0: 45 kt (1.6% of east)).
#44 (2 A II ++ L) TOT=5786	<ul style="list-style-type: none"> - Strange trend in west area biomass (steep decline from 2010). This is caused by steep decline of eastern fish moving to west

#46 (1 B II ++ L) TOT=5967	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.2 Mt, B0; 3.4 Mt). Very high recruitment in recent years. Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times. - West stock: very low biomass relative to east (current B; 18 kt (1.5% of east), B0: 63 kt (1.9% of east)).
#47 (2 B II ++ L) TOT=6221	<ul style="list-style-type: none"> - Strange trend in west area biomass (steep decline from 2010). This is caused by steep decline of eastern fish moving to west. - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times.
#49 (1 A I – H) TOT=10133	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.0 Mt, B0; 2.0 Mt). Very high recruitment in recent years. - West stock: very low biomass relative to east (current B; 11 kt (1.1% of east), B0: 39 kt (1.9% of east)).
#50 (2 A I – H) TOT=10790	<ul style="list-style-type: none"> - Only about 20-30% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times.
#52 (1 B I – H) TOT=10772	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 946 kt, B0; 2.4 Mt). - West stock: very low biomass relative to east (current B; 9 kt (0.97% of east), B0: 61 kt (2.6% of east)).
#53 (2 B I – H) TOT=11261	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times.
#55 (1 A II – H) TOT=9852	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.0 Mt, B0; 2.0 Mt). Very high recruitment in recent years. - West stock: very low biomass relative to east (current B; 11 kt (1.1% of east), B0: 42 kt (2.1% of east)).
#56 (2 A II – H) TOT=10577	<ul style="list-style-type: none"> - Only about 20-30% of biomass in MED in Apr-Jun. Majority of eastern fish (as high as 80%) is in SATL in most of times.
#58 (1 B II – H) TOT=10513	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.0 Mt, B0; 2.4 Mt). - West stock: very low biomass relative to east (current B; 8 kt (0.8% of east), B0: 62 kt (2.5% of east)).
#59 (2 B II – H) TOT=11195	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (60-80%) is in SATL in most of times.
#61 (1 A I ++ H) TOT=10061	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.4 Mt, B0; 2.4 Mt). Very high recruitment in recent years. - West stock: very low biomass relative to east (current B; 10 kt (0.76% of east), B0: 39 kt (1.6% of east)).
#62 (2 A I ++ H) TOT=10677	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (50-80%) is in SATL in most of times.
#64 (1 B I ++ H) TOT=10694	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.3 Mt, B0; 2.8 Mt). Very high recruitment in recent years. - West stock: very low biomass relative to east (current B; 8 kt (0.6% of east), B0: 61 kt (2.2% of east)).
#65 (2 B I ++ H) TOT=11310	<ul style="list-style-type: none"> - Only less than 20% of biomass in MED in Apr-Jun. Majority of eastern fish (almost always 80%) is in SATL in most of times.
#67 (1 A II ++ H) TOT=9824	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.3 Mt, B0; 2.3 Mt). Very high recruitment in recent years. - West stock: very low biomass relative to east (current B; 13 kt (1.0% of east), B0: 44 kt (1.9% of east)).
#68 (2 A II ++ H) TOT=10463	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (50-80%) is in SATL in most of times.
#70 (1 B II ++ H) TOT=10426	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 1.3 Mt, B0; 2.8 Mt). Very high recruitment in recent years. - West stock: very low biomass relative to east (current B; 8 kt (0.6% of east), B0: 62 kt (2.2% of east)).
#71 (2 B II ++ H) TOT=10877	<ul style="list-style-type: none"> - Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (about 80%) is in SATL in most of times.
#73 (1 A I +- H) TOT=9892	<ul style="list-style-type: none"> - East stock: very high biomass (current B; 948 kt, B0; 2.0 Mt). Very high recruitment in recent years.

#74 (2 A I +- H) TOT=10472	-
#76 (1 B I +- H) TOT=10293	-
#77 (2 B I +- H) TOT=11019	- Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (about 80%) is in SATL in most of times.
#79 (1 A II +- H) TOT=9695	- East stock: very high biomass (current B; 1.1 Mt, B0; 2.1 Mt). Very high recruitment in recent years.
#80 (2 A II +- H) TOT=10320	-
#82 (1 B II +- H) TOT=10151	-
#83 (2 B II +- H) TOT=11026	- Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (70-80%) is in SATL in most of times.
#85 (1 A I ++ H) TOT=9884	- East stock: very high biomass (current B; 1.5 Mt, B0; 2.5 Mt). Very high recruitment in recent years.
#86 (2 A I ++ H) TOT=10354	- Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (70-80%) is in SATL in most of times.
#88 (1 B I ++ H) TOT=10257	- East stock: very high biomass (current B; 1.1 Mt, B0; 2.6 Mt). Very high recruitment in recent years.
#89 (2 B I ++ H) TOT=10731	- Only less than 20% of biomass in MED in Apr-Jun. Majority of eastern fish (over 80%) is in SATL in most of times.
#91 (1 A II ++ H) TOT=9606	- East stock: very high biomass (current B; 1.5 Mt, B0; 2.5 Mt). Very high recruitment in recent years.
#92 (2 A II ++ H) TOT=10213	- Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (50-80%) is in SATL in most of times.
#94 (1 B II ++ H) TOT=10113	- East stock: very high biomass (current B; 1.2 Mt, B0; 2.7 Mt). Very high recruitment in recent years.
#95 (2 B II ++ H) TOT=10764	- Only about 20% of biomass in MED in Apr-Jun. Majority of eastern fish (70-80%) is in SATL in most of times.