AN EXPLORATION OF BLUEFIN TUNA DATA IN THE NORTH ATLANTIC (WEST AND EAST + MEDITERRANEAN) WITH ASAP

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SUMMARY

We use ASAP from the USA NOAA Toolbox to explore various combinations of model configurations and length of the data series for bluefin tuna in the West Atlantic and in the East Atlantic + Mediterranean. Using the data from the 2014 assessment for the West Atlantic, ASAP provided SSB and recruitment trends similar to those in the base case VPA in some runs but considerably greater SSB in 1970 for one of the runs. Extending the catch at age to 2015 and using the updated stock size indices provides similar SSB for 1970 to 1990, but SSB increases more rapidly since 1990 than when using the new catch at age to 2014. Extending the catch at age to 1960 provides even greater initial SSBs, but extending it further to 1950 suggests low SSBs in the 1950s and 1960s. For the East Atlantic + Mediterranean, ASAP results are similar to those from the VPA. The influence of each stock size index is evaluated by removing each one at a time.

RÉSUMÉ

Nous utilisons ASAP de la boîte à outils de la NOAA des Etats-Unis pour explorer les diverses combinaisons de configurations du modèle et la longueur de la série de données pour le thon rouge de l'Atlantique Ouest et de l'Atlantique Est + Méditerranée. En utilisant les données de l'évaluation de 2014 pour l'Atlantique Ouest, ASAP a fourni des tendances de la SSB et du recrutement qui sont semblables à celles du cas de base de la VPA dans certains scénarios mais une SSB considérablement plus élevée en 1970 pour l'un des scénarios. Le fait d'étendre la prise par âge jusqu'en 2015 et d'utiliser les indices de la taille du stock mis à jour fournit une SSB similaire de 1970 à 1990, mais la SSB augmente plus rapidement depuis 1990 que si l'on utilise la nouvelle prise par âge jusqu'en 2014. Le fait d'étendre la prise par âge jusqu'en 1960 fournit des SSB initiales encore plus grandes, mais le fait de la prolonger davantage jusqu'en 1950 suggère des SSB faibles dans les années 50 et 60. Pour l'Atlantique Est + Méditerranée, les résultats d'ASAP sont similaires à ceux de la VPA. L'influence de chaque indice de la taille du stock est évaluée en en supprimant un à la fois.

RESUMEN

Hemos utilizado ASAP de las Herramientas de la NOAA de Estados Unidos para explorar diversas combinaciones de configuraciones del modelo y longitud de series de datos para el atún rojo del Atlántico oeste y del Atlántico este + Mediterráneo. Con los datos de la evaluación de 2014 para el Atlántico occidental, ASAP proporcionaba tendencias similares en la SSB y el reclutamiento a las del caso base del VPA en algunos ensayos, pero una SSB considerablemente mayor en 1970 en uno de los ensayos. Al ampliar la captura por edad hasta 2015 y utilizar los índices actualizados del tamaño del stock se obtenía una SSB similar para el periodo 1970 a 1990, pero la SSB aumentaba más rápido desde 1990 que cuando se utilizaba la nueva captura por edad hasta 2014. Ampliar la captura por edad hasta 1960 proporciona unas SSB iniciales aún mayores, pero ampliándola hasta 1950 sugiere SSB más bajas en los 50 y los 60. Para el Atlántico este + Mediterráneo, los resultados de ASAP eran similares a los del VPA. Se evalúa la influencia de cada índice del tamaño del stock eliminando uno cada vez.

KEYWORDS

Bluefin tuna, western Atlantic, stock assessment, length of time series

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Introduction

The assessment of Atlantic bluefin tuna in 2017 is a benchmark assessment. The SCRS encouraged scientists to apply assessment methods other than the VPA used in the previous full assessment (2014). We use an Age Structured Assessment Program (ASAP, http://nft.nefsc.noaa.gov/ASAP.html) developed for and using bluefin tuna as an example (Legault and Restrepo 1998).

The Age Structured Assessment Program (ASAP) uses forward projections of stock abundance assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance. The constant selectivity assumption associated with separability can be made more realistic by allowing for fleet-specific selectivity and by allowing the selectivity at age to change smoothly over time or in multi-annual periods. The software can also allow the catchability associated with each abundance index to vary smoothly with time. Dimensions of the statistical model (number of ages, years, fleets and abundance indices) are defined by the available data (with allowances for missing data in some years) but may also be limited by information content for estimation of all parameters. The model does not allow use of length data nor indices of survival rates. Diagnostics include index fits, residuals in catch and catch-at-age, and effective sample size calculations. Weights are input for different components of the objective function and allow for relatively simple age-structured production model type models up to fully parameterized models. Projections can be performed in the same framework once an acceptable model has been found.

Data

The 2017 Atlantic bluefin tuna assessment involved an in-depth review of the data used in the assessment. The catch at age (CAA, ages 1 to 16plus, Table 1), weights at age (WAA, ages 1 to 16plus, Table 2) and total landings in tons (Table 3) were extracted from *CAA_WBFT_2017_sclice v4.xlsx* posted on the Owncloud by the ICCAT Secretariat on July 3, 2017. The usual cohort slicing approach and modal analyses were used, and included Canadian size samples for 1974 to 1985 instead of the USA RR substitutions in previous files. Data for the East Atlantic + Mediterranean were supplied by Ai Kimoto (pers. com.)

In ASAP it is possible to use several fleets, but in this initial exploration, a single fleet including all catches by all fleets was used. Changes in selectivity over time due to changes in the dominance of the various gears are approximated by allowing periods with different selectivities.

Stock size indices were as agreed at the March 2017 Data Preparatory meeting, except for the Canadian Combined RR (which was not smoothed) and tagging which was not used. All indices for the West Atlantic are in numbers, except for the larval index in the Gulf of Mexico that is in biomass, and considered to index the stock in month 6. The table of indices of stock size is too large to be included in this document. It is in the Analysis Folder of the Owncloud in the EXCEL spreadsheet _WBFT2017 input CAA WAA etc. version 4 July 4.xlsx. Selectivity was not estimated for each fleet, but the ages to which the index applies were all considered equally selected. For the East Atlantic + Mediterranean, the data used were the same as in the VPA.

Natural mortality and maturity (spawning fraction)

The natural mortality and maturity (spawning fraction) were taken from the file "**BFT parameters_ML.xlsx**" received from Clay Porch on May 18, 2017.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16P**
M	.38	.3	.24	.2	.18	.16	.14	.13	.12	.12	.11	.11	.11	.1	.1	.1
Mat	0	0	.25	.5	1	1	1	1	1	1	1	1	1	1	1	1

Initial values to start the ASAP calculations were rounded values from the most recent VPA run in the Annex of the 2014 detailed report.

For comparison with the 2014 assessment results for the West Atlantic, M=0.14 for all ages and knife edge maturity at age 9 were used.

ASAP configurations for the West Atlantic

The first step was to make five ASAP runs under various model settings and compare the results with those of the 2014 stock assessment. Table 4 summarizes the settings: the runs were consecutive from left to right with the highlighted cells indicating changed values from the previous runs.

For all runs for the West Atlantic, the **Phases** where various parameters are estimated were kept the same (Phase for F mult in 1st Year = 1, Phase for F mult Deviations = 3, Phase for Recruitment Deviations = 3, Phase for N in 1st Year = 2, Phase for Catchability in 1st Year = 1, Phase for Catchability Deviations = -1, Phase for Stock Recruitment Relationship = 1, Phase for Steepness = -4) , the **lambdas** for the index were all set to 1 as were the **lambdas** for the single fleet catch at age. The **CVs** for the total catch by year were set to 0.01 and the input Effective Sample Size were set to 50 except when data prior to 1970 were used, the CVs for the total catch were increased to 0.1 and the input sample size was decreased to 10. The Lambdas for **F Mult in First year** were set to 0 and the CV for F Mult in First year set to 0.9. The **CV for F Mult Deviations** by Fleet were set at 0.9 for all runs. The **Lambdas for N in 1st Year Deviations** were set at 0 for all runs. The **CVs for N in 1st Year Deviations** were set at 0.9, the **Lambdas for Recruitment Deviations** were set at 1. The CVs for **Catchability in First year by Index** were set at 0.9 for all runs. The **Lambda for Deviation from Initial Steepness** was set at 0 and the CVs for **Deviation from Initial Steepness** at 0.9. The **Lambdas for Deviation from Unexploited Stock Size** were set to 0 and the **CVs for Deviation from Unexploited Stock Size** were set at 0.9.

For Run 1:
Lambda for F Mult in First year = 0
CV for F Mult in First year = 0.9
Lambda for F Mult Deviations = 0
CV for F Mult Deviations = 0.9
Lambda for N in 1st Year Deviations = 0
CV for N in 1st Year Deviations = 0.9
Lambda for Recruitment Deviations = 1
Lambda for Catchability in First year by Index = 0 0 0 0 0 0 0 0 0 0 0 0 0
CV for Catchability in First year by Index = 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9
Lambda for Catchability Deviations by Index = 0 0 0 0 0 0 0 0 0 0 0 0
CV for Catchability Deviations by Index = 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
Lambda for Deviation from Initial Steepness = 0
CV for Deviation from Initial Steepness = 0.9
Lambda for Deviation from Unexploited Stock Size = 0
CV for Deviation from Unexploited Stock Size = 0.9

For Run 2, Lambda for Catchability in First year by Index = 1 1 1 1 1 1 1 1 1 1 1 1 which imposes a penalty term in the objective function for deviating from the starting guesses of catchability. This was used to illustrate how ASAP works more than a realistic run.

For Run 3:
Recruitment CV by Year = 0.9 instead of 2
Lambda for F Mult Deviations = 0.1 instead of 0
Lambda for Catchability in First year by Index = 0 0 0 0 0 0 0 0 0 0 0 0 0 as in Run 1.

For Run 4, Lambda for F Mult Deviations = 1 instead of 0.1 in Run 3.

For Run 5, Lambda for F Mult Deviations = 10 instead of 1 in Run 4.

SSB from the Runs are shown in **Figure 1**. Runs 1, 2, 4 and 5 show slight increases in biomass for the first few years, followed by a steady decline to a minimum in the early 2000s followed by an increase. In Run 3, SSB is very high in 1970 with a steep decrease to the late 1990s when the SSB trend becomes similar to the other runs. Runs 4 and 5 are undistinguishable from Run 1.

Recruitment estimates from the various runs (**Figure 2**) are consistent even for Run 3 where SSB was considerably higher.

The separable fishing mortality multiplier (FMult **Figure 3**) show very similar trends with runs 1, 4 and 5 being undistinguishable. Run 2 gives consistently lower FMult and Run 3 consistently higher FMult as could be expected from the relative SSB trends.

Compared with the VPA, the changes in SSB (**Figure 4**) is less with ASAP, but ASAP estimates start lower in 1970 and end higher in 2013. Recruitment estimates (**Figure 6**) are reasonably consistent between run 4 and the VPA.

For Run 6, the new catch at age was used with the settings of Run 4 and the indices of stock size not updated. For Run 7, the new CAA was used up to 2015 and the new stock size indices were used. The new CAA, either with the old or with the new stock size indices does change SSB absolute values and relative trends (**Figure 6**). Changing the earliest year in the series also makes a difference with Run 8 starting in 1960 and Run 9 in 1950 (**Figure 7**). Extending to 1960 produced very high initial SSB with a declining trend overlapping the SSB estimates from the analysis starting in 1970. However, extending the analysis to 1950 (Run 9) produced substantially lower initial biomass that remained lower than in the other two analyses (Runs 7 and 8) until the late 1980s when SSB estimates were similar for those three analyses. While the runs starting in 1960 and in 1970 produced relatively high SSBs, most of the biomass was in the age 16Plus group and the exploitable biomass (i.e. the total biomass times the selectivity) were very similar regardless of the starting year. The problem of high SSBs when starting in 1960 or 1970 was solved by setting Lambda =1 on initial numbers and using a low CV=0.1.

With this configuration, SSB in 1950 is slightly below 100 000t (**Figure 8**), increases slowly to 110 000 in 1962 before a steady decline to less than 20 000t in the early 1990s. SSB subsequently increases three fold with the 2015 SSB similar to that in 1968 at about 60000t. A retrospective analysis showed relatively consistent SSB estimates when years were removed from the analysis (**Figure 9**).

The influence of each index on the results was evaluated by removing each index ('jacknife'), one at a time (**Figure 10**). SSB estimates are reasonably consistent for all removals except when the larval index and the Canadian Rod and Reel are removed. Removing the larval index produces larger SSB increases in recent years to about 80000t, and removing the Canadian Rod and Reel results in little increase in SSB since the mid 1990s with 2015 SSB slightly below 30000t.

ASAP configurations for the East Atlantic + Mediterranean

The configuration for the East Atlantic and Mediterranean was similar to that for the West Atlantic: ages 1 to 16plus, catch at age for a single fleet 1950 to 2015, the same biological parameters as agreed at the data meeting in 2017 for M and fraction spawning. Weights at age were from the ratio of total yield in mass to the total numbers caught. The same stock size indices as in the VPA were used. The fits to the stock indices were similar to those in the VPA, but those to the proportions at age could be improved with fine tuning of the selectivity blocks. The SSB trends with all the indices included were close to those of the VPA from the early 1980s onward and almost identical for 2007-2015 (**Figure 11**).

The retrospective analysis (**Figure 12**) shows consistent SSB estimates when the first three years of data are removed, but considerably lower SSB when 4 and 5 years of data are removed. This suggests that recent indices, the French aerial survey and the larval index, may have a large influence on the results, particularly if they are considered as a consistent continuous series when changes have in fact occurred. **Figure 13** shows that removing the larval index or splitting the larval index and the French aerial survey results in considerably smaller SSBs. Although the larval index is an index of SSB, using it in the calibration produces, like in the VPA, a number of relatively strong year classes post 2003. Removing the larval index from the calibration reduces considerably the size of the year classes since 2003 (**Figure 14**).

References

Legault, C.M. and Restrepo, V.R. 1998. A Flexible Forward Age-Structured Assessment Program. ICCAT SCRS/1998/58.

Table 1. WBFT Total catch at age.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16P
1950	893.0	1255.5	9223.6	6988.3	898.5	1.6	1.5	31.1	69.7	106.9	194.3	248.6	325.7	312.2	340.2	816.6
1951	1632.3	7863.5	13576.7	10867.9	1491.1	8.3	0.3	19.5	46.0	67.8	117.9	159.8	238.7	254.2	249.9	736.2
1952	200.9	1010.1	5144.4	3948.3	511.2	1.7	12.7	47.5	58.0	76.1	137.9	177.4	239.5	232.9	246.7	620.3
1953	284.9	1136.2	19643.9	14834.9	1875.1	0.3	2.0	16.8	30.5	46.8	84.6	112.9	142.0	146.4	156.3	441.3
1954	1135.9	4505.7	13790.2	10724.3	1417.7	4.6	0.6	9.8	23.5	33.2	58.0	76.4	123.3	125.9	123.3	328.0
1955	160.4	530.3	9669.2	7298.1	922.1	0.7	9.2	27.5	27.1	31.4	57.5	71.3	84.9	76.3	87.9	186.1
1956	35.2	5.1	2123.1	3803.5	1183.7	91.5	0.1	3.1	7.0	10.8	19.6	24.7	35.0	32.9	35.0	80.7
1957	263.9	39.5	4756.3	8494.7	2645.4	209.9	84.0	174.0	75.9	21.4	42.2	51.6	55.7	51.6	56.2	120.4
1958	2026.7	9486.4	812.8	1829.8	1660.6	2207.2	5205.4	1508.4	429.5	98.6	120.7	85.8	68.2	74.4	76.4	217.3
1959	11021.8	52227.5	2275.6	6316.2	2576.5	3563.7	1537.2	1211.0	528.0	127.3	221.1	244.9	166.2	170.8	179.1	392.4
1960	4705.2	19831.2	1234.3	2412.0	839.4	830.5	1510.7	1432.1	547.7	113.8	227.0	264.8	195.1	146.1	167.9	317.2
1961	14299.1	61035.2	2867.2	7258.6	1987.4	278.8	1004.4	1463.3	626.3	137.8	236.5	292.3	247.2	226.2	238.1	518.9
1962	54600.8	252820.4	11138.7	30003.1	8092.6	734.6	3021.5	5174.0	2245.6	450.6	735.4	904.8	693.6	647.5	658.7	1417.5
1963	82648.7	387271.7	17000.5	46092.0	12546.5	1686.3	12845.7	24518.2	9929.4	1467.5	2790.2	3347.3	1851.6	1459.3	1771.2	3072.6
1964	75908.4	346848.4	15580.5	41502.5	11520.3	2499.2	23711.8	45963.1	18278.8	2370.9	4866.6	5631.0	2079.9	1459.5	2166.7	2381.6
1965	49711.4	223941.2	9915.4	26813.7	7419.3	1532.0	17512.0	35098.4	13963.1	1832.5	3739.1	4415.0	1946.1	1394.8	1959.4	2795.7
1966	16748.9	68262.2	3271.3	8198.1	2311.9	619.5	5940.3	11451.9	4544.6	855.5	1491.5	2219.3	2935.4	2254.0	2439.3	6549.7
1967	32245.6	140973.3	6535.4	16827.3	4654.4	889.3	6390.9	11729.5	4703.4	672.3	1325.9	1568.8	786.8	615.8	779.5	1257.6
1968	10040.3	46138.1	1997.0	5511.6	1508.8	247.8	3022.4	6168.3	2469.6	369.7	712.6	910.5	687.7	551.6	675.6	1467.7
1969	18262.4	75208.3	3429.5	8927.9	2401.4	159.1	1083.7	2216.1	950.8	230.8	359.6	565.4	847.5	772.9	830.8	2285.2
1970	62742.2	293757.3	19812.5	19369.5	9069.4	369.1	499.0	1078.2	709.5	293.4	351.9	501.3	678.5	762.2	721.3	2115.5
1971	56905.0	258897.1	7115.8	27150.8	8036.3	460.2	2535.4	5220.4	2314.5	515.1	820.6	1096.6	1106.7	1044.4	1083.3	2833.7
1972	32323.2	137789.0	2263.7	15972.4	4260.9	368.6	1038.6	1285.9	585.7	142.5	176.5	267.8	1004.9	1338.0	876.1	2790.0
1973	27151.9	113656.6	1817.9	13108.1	3491.5	791.2	3291.6	3981.7	1447.1	124.3	140.9	268.0	474.2	1242.3	567.8	2215.9
1974	55307.6	75710.7	1123.9	8429.6	2430.7	148.8	676.5	660.3	1974.9	1681.2	1711.3	701.2	1347.9	1684.5	1712.4	5592.1

1975	35540.1	154198.1	6787.0	18397.1	4959.2	211.6	50.7	287.6	919.5	1232.2	1237.3	1121.6	1740.7	1455.4	1122.6	3317.5
1976	8142.4	35471.6	56880.5	18979.4	3770.2	1651.3	164.5	297.4	666.4	634.4	1136.5	2018.6	2608.5	1817.9	1867.1	4691.8
1977	1124.1	17520.4	11289.0	18560.7	30914.3	3674.6	2997.1	414.5	312.3	366.9	529.3	742.4	2010.7	1882.0	1924.2	7817.7
1978	2021.2	9633.8	13352.1	18338.8	11148.0	9537.3	1179.5	553.1	450.5	350.6	445.6	587.0	1307.3	1092.0	1506.0	7773.9
1979	2148.4	4739.5	13367.1	15474.6	17152.5	2721.7	4620.6	1857.9	604.0	515.9	567.8	1151.6	1917.6	1479.4	1876.8	7001.7
1980	3479.7	9732.3	14048.4	10042.9	8729.0	2466.7	4139.2	6087.2	2110.7	665.4	667.2	620.7	717.9	1077.3	1161.8	6691.4
1981	6890.9	5572.0	25807.3	885.8	10073.2	4902.0	2545.4	2302.4	3274.6	1771.0	1142.0	1011.2	806.9	857.1	956.6	6006.2
1982	3637.0	2421.2	3092.4	1342.5	376.9	594.1	697.2	497.4	668.3	830.4	789.3	395.9	181.2	189.0	156.1	2159.2
1983	3876.0	1888.8	2248.9	2071.1	1488.2	1343.0	1517.3	1605.7	1363.7	842.6	1007.0	814.7	656.6	451.7	299.1	2540.8
1984	554.4	5048.8	3417.7	2238.6	4511.8	2696.6	1174.3	572.2	859.9	972.3	898.8	968.4	731.8	597.1	328.5	1533.0
1985	482.3	4260.7	8317.4	7189.2	4478.2	4843.1	2886.1	811.6	563.6	607.8	776.7	1039.1	1021.1	816.7	627.1	1516.7
1986	582.1	5517.7	8910.0	3535.1	6461.8	2653.8	1713.4	1601.6	755.7	503.2	520.0	716.1	648.3	624.5	450.3	1278.5
1987	1385.1	12117.7	10914.8	6860.5	7265.5	4561.9	1654.5	1363.5	1132.7	637.3	472.5	607.4	485.1	523.4	381.4	1088.3
1988	5675.0	4847.0	14914.3	6401.6	4998.2	4594.9	3900.7	2084.1	1517.3	944.6	653.8	675.9	506.4	522.8	403.8	1381.5
1989	672.6	5248.4	9080.2	2045.6	4753.3	1985.4	2826.0	3010.9	1552.1	1205.3	1009.8	805.1	583.2	549.4	395.6	1471.6
1990	1513.1	2968.4	19122.1	6091.5	3408.9	3254.7	1732.2	2123.7	2222.5	1024.3	847.8	647.0	476.5	539.2	353.6	1334.4
1991	1022.4	4978.2	22366.9	3891.3	3111.5	1994.7	2582.1	2410.8	2297.5	1668.1	1023.8	734.3	550.5	518.9	331.5	1008.5
1992	42.2	2044.6	6319.2	1025.7	2054.8	1830.6	1568.0	2420.1	1530.6	1265.7	1258.9	892.8	478.8	465.7	304.7	1103.3
1993	226.0	628.2	1391.6	6263.7	3677.0	1761.1	2629.9	1972.8	2858.4	1216.0	761.0	502.2	351.0	340.9	229.4	1193.5
1994	1017.4	1705.6	837.0	2080.9	3502.0	2349.5	1709.8	3314.5	1842.5	1377.9	868.2	534.0	309.5	274.8	188.6	916.4
1995	449.6	642.6	2554.8	5080.4	4625.5	3968.2	1182.6	1657.0	2167.5	1306.1	746.4	571.5	368.4	391.4	227.6	1423.8
1996	256.2	4109.8	7838.2	4184.5	4554.9	2991.0	1869.4	2206.1	1020.2	1442.5	1046.5	730.8	492.4	495.8	331.1	1217.9
1997	151.8	377.1	4665.0	3866.3	1916.2	1793.3	1678.8	2727.7	1765.1	877.9	901.9	827.8	567.3	543.5	283.1	1251.2
1998	218.9	488.6	2876.9	4512.3	1968.3	1520.9	1740.0	3277.0	2955.7	1681.4	898.1	801.7	655.6	452.5	249.4	1151.7
1999	34.7	412.7	997.4	2403.4	3585.5	2244.0	2163.4	2105.5	2024.1	2492.2	1774.9	838.4	499.5	439.5	273.1	1078.6
2000	53.5	239.7	860.3	602.4	2092.6	4088.1	1864.7	1992.9	2174.7	1507.3	1472.6	1079.2	734.1	448.7	326.1	1449.9
2001	1042.1	685.8	1011.3	5062.2	2630.7	1683.5	3143.0	2719.9	889.9	1392.5	1351.7	1240.5	839.6	656.8	360.3	1159.4

2002	5.2	4165.3	5748.5	4323.7	7388.2	2636.5	2304.5	4189.7	2448.1	1240.2	1082.9	1096.4	954.7	800.7	412.8	1139.1
2003	79.3	1257.5	3931.1	5443.1	2793.8	1778.8	552.0	1956.5	2339.7	1182.5	573.7	621.5	609.2	642.9	289.2	1141.9
2004	12.5	1728.5	5069.6	6216.9	3625.2	2451.9	2672.3	1377.4	1364.5	1221.7	624.8	474.3	392.9	308.8	204.1	1124.8
2005	400.5	4721.0	2720.6	3596.5	1297.7	826.4	856.0	1197.4	953.5	1156.2	1086.7	686.1	420.0	302.0	202.9	1089.6
2006	88.2	249.7	1451.2	1133.2	3276.7	1690.5	1154.8	1284.6	1286.0	964.8	803.4	514.4	482.4	408.4	234.9	1166.9
2007	57.8	75.5	985.9	15159.6	2814.0	2478.0	1379.8	918.0	541.9	498.6	399.6	334.9	286.5	224.3	153.1	858.7
2008	65.8	212.4	1378.9	2193.4	8242.6	1534.8	2131.8	1518.1	1026.6	765.2	421.6	396.2	388.9	238.3	203.2	1158.0
2009	25.4	80.5	1140.6	2211.8	1465.3	5870.5	1526.4	1371.9	1336.8	944.9	521.4	440.1	477.3	332.2	273.2	1058.2
2010	29.8	524.3	991.4	1694.2	1670.1	824.0	1614.8	1654.5	1352.3	1475.5	754.9	500.4	536.1	389.7	287.3	998.8
2011	0.0	92.5	682.7	2892.6	1728.8	2291.4	1095.7	4323.3	1274.5	818.3	795.3	586.0	394.1	324.7	239.0	917.2
2012	46.4	166.7	1050.2	2168.8	1035.8	814.7	836.7	1455.2	2163.1	1362.2	559.7	577.2	416.0	356.5	267.9	867.2
2013	8.6	155.0	299.8	1258.6	564.1	585.3	511.0	1362.8	818.9	1357.0	1048.0	530.5	407.4	290.1	190.1	826.2
2014	10.0	572.2	708.8	1038.3	533.5	657.6	209.4	658.7	1209.5	1268.3	1198.4	948.2	608.9	360.5	202.2	800.9
2015	0.0	1.6	655.2	945.6	421.6	341.0	629.9	886.5	720.2	1333.1	1317.6	1012.1	735.9	532.2	326.1	1061.4

Table 2. WBFT Weights at age.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16P
1950	3.2	7.3	15.1	26.0	34.7	64.4	78.4	122.3	146.5	171.9	201.2	222.9	244.1	261.3	279.6	319.7
1951	3.3	7.4	15.1	25.9	34.7	60.2	92.0	122.6	146.6	172.0	201.3	222.5	242.6	259.8	278.8	319.6
1952	3.4	7.4	15.1	26.0	34.7	63.0	85.4	112.5	143.6	171.9	201.1	222.6	243.6	260.8	279.5	319.7
1953	3.5	7.4	15.1	26.0	34.7	65.3	84.7	118.5	145.9	171.8	201.2	222.5	244.0	260.7	279.2	320.5
1954	3.3	7.4	15.1	25.9	34.7	60.7	81.2	122.3	146.2	172.0	201.2	222.8	242.2	259.9	278.8	318.6
1955	3.5	7.3	15.1	26.0	34.7	66.3	85.3	110.1	141.9	171.9	200.9	222.7	244.9	262.2	280.2	320.1
1956	3.1	6.8	16.5	23.8	40.8	54.4	78.2	122.4	146.6	171.9	201.3	223.1	243.6	261.0	279.7	319.1
1957	3.1	7.0	16.5	23.8	40.8	54.7	85.3	104.5	130.7	171.6	195.3	215.9	240.6	259.7	276.7	317.9
1958	3.3	7.4	13.7	25.0	40.8	62.5	86.2	109.2	135.5	170.6	194.2	214.9	240.6	259.5	276.1	319.7
1959	3.3	7.4	12.3	25.7	38.3	61.5	83.5	105.2	131.8	171.7	193.7	213.8	239.9	260.7	275.4	318.4
1960	3.3	7.4	12.8	25.5	37.3	61.4	85.7	104.7	130.0	171.8	191.8	212.1	238.2	258.0	272.3	316.8
1961	3.3	7.4	12.3	25.7	34.9	61.6	85.7	104.6	130.7	172.2	192.2	212.3	236.5	257.1	271.1	314.4
1962	3.3	7.4	12.3	25.7	34.8	61.8	85.6	104.5	130.7	172.4	191.2	210.7	234.5	256.1	269.2	313.0
1963	3.3	7.4	12.3	25.7	35.1	63.0	85.5	104.2	129.3	171.8	188.7	206.9	229.8	252.1	264.2	311.5
1964	3.3	7.4	12.3	25.7	35.5	63.7	85.4	104.2	128.9	171.6	187.8	205.5	226.5	251.6	261.7	311.6
1965	3.3	7.4	12.2	25.7	35.6	64.4	85.4	104.2	128.8	171.5	187.8	205.6	227.0	250.1	261.9	311.3
1966	3.3	7.4	12.2	25.7	35.8	63.8	85.4	104.2	128.9	171.1	189.6	208.0	230.4	247.1	263.4	310.5
1967	3.3	7.4	12.3	25.7	35.3	62.9	85.5	104.2	129.1	171.7	188.5	206.8	230.0	253.1	264.6	312.5
1968	3.3	7.4	12.2	25.7	35.4	64.7	85.4	104.2	128.9	171.4	188.7	207.0	230.3	249.6	264.8	312.8
1969	3.3	7.4	12.1	25.7	34.8	62.9	85.4	104.3	130.1	171.5	191.7	211.0	233.0	250.6	267.4	313.4
1970	3.3	7.4	20.5	28.4	34.6	60.8	85.5	105.6	136.1	173.1	197.1	218.4	238.7	257.8	273.7	318.0
1971	3.3	7.4	17.5	26.3	34.7	62.3	85.4	104.4	130.7	172.1	192.1	211.6	234.5	254.4	269.3	315.1
1972	3.3	7.4	16.1	25.7	34.6	57.6	89.1	112.4	140.6	173.2	201.0	223.3	238.3	259.8	277.3	317.6
1973	3.3	7.4	16.2	25.7	34.6	56.1	89.1	112.1	139.3	172.8	200.8	220.9	239.6	263.9	274.3	321.7
1974	3.2	7.5	16.1	25.8	34.7	63.3	96.9	127.0	154.5	178.0	202.8	220.5	239.8	258.5	274.1	319.6

1975	3.3	7.4	12.2	25.7	34.7	60.1	90.6	117.1	143.8	168.8	195.4	219.6	238.9	257.8	273.2	319.2
1976	3.2	7.6	14.8	19.9	34.5	51.2	84.6	123.4	142.9	167.7	194.8	218.4	243.6	262.6	280.2	330.1
1977	3.3	7.7	10.5	21.7	33.0	53.9	72.4	100.6	137.9	169.9	194.1	220.2	244.5	265.8	281.8	332.6
1978	3.7	6.5	12.6	19.8	35.9	55.5	76.2	112.9	144.5	175.4	199.0	222.2	247.9	266.4	283.3	340.8
1979	4.2	6.7	11.5	20.5	35.2	59.5	80.1	104.3	137.1	172.5	199.9	223.5	249.9	267.5	286.4	344.5
1980	4.3	9.5	13.4	22.8	36.2	61.8	88.7	109.0	140.4	173.3	200.1	221.2	243.2	258.9	278.2	337.1
1981	5.0	7.9	16.0	25.1	36.5	58.6	80.7	108.3	141.5	168.5	193.2	219.3	247.2	262.7	281.4	366.9
1982	3.1	7.0	11.7	22.9	40.6	62.0	86.3	114.2	142.5	171.1	196.3	216.4	238.8	256.6	277.3	357.1
1983	3.5	7.3	14.1	22.6	41.3	59.9	85.8	113.1	139.9	170.4	198.0	220.6	239.4	258.4	274.3	357.1
1984	3.2	7.2	11.8	22.2	37.0	62.3	87.0	113.2	143.1	171.8	196.3	221.4	241.1	260.2	277.3	358.9
1985	2.6	7.4	13.1	17.1	34.5	54.3	72.4	98.8	135.2	166.7	192.9	216.5	238.6	256.3	274.1	336.3
1986	3.1	6.7	14.3	26.9	36.2	62.6	85.9	110.3	141.8	168.9	198.2	219.2	241.7	260.1	278.6	334.5
1987	3.0	6.8	16.1	25.7	39.0	56.8	84.4	108.3	138.4	167.4	195.2	218.9	242.3	259.1	278.7	334.5
1988	2.9	7.2	13.0	23.4	38.5	58.3	80.3	109.7	139.5	169.6	196.3	218.4	241.2	259.4	278.6	334.0
1989	3.1	7.6	10.1	25.3	38.0	59.9	86.0	111.5	142.2	169.1	193.3	217.9	238.8	256.7	275.7	336.2
1990	3.6	6.8	15.9	20.9	38.2	60.7	84.3	113.5	142.2	169.4	194.4	218.6	238.7	257.9	278.1	329.0
1991	3.5	6.2	14.6	26.0	41.6	64.1	87.9	116.2	144.9	169.6	195.8	219.6	242.2	261.4	280.5	335.3
1992	3.1	7.4	13.2	23.2	38.5	62.3	85.9	110.7	139.8	170.0	194.4	218.8	239.7	260.1	277.2	336.0
1993	3.6	6.9	13.3	24.0	40.5	60.1	82.6	113.0	138.0	165.7	194.8	217.3	238.5	258.2	276.8	341.8
1994	3.1	4.8	12.6	22.0	35.8	53.4	78.3	110.9	136.9	168.7	193.4	217.3	237.3	258.3	279.0	338.1
1995	3.1	5.0	14.0	25.0	40.8	60.9	84.1	110.9	142.7	167.2	194.7	217.6	240.0	259.2	278.6	348.9
1996	2.9	7.6	10.5	26.7	38.2	55.1	89.0	109.8	143.1	171.7	197.4	218.8	241.8	260.9	279.9	342.1
1997	3.9	6.9	14.9	19.8	40.3	61.6	85.0	111.2	139.6	169.4	197.6	220.0	240.4	258.4	277.2	338.0
1998	3.7	6.5	14.1	23.8	36.3	64.9	86.3	114.1	142.0	168.5	197.0	219.8	240.4	258.1	275.9	339.6
1999	3.7	8.1	15.1	24.3	44.2	64.8	89.5	112.6	142.6	168.0	193.6	221.7	243.0	261.0	279.5	362.9
2000	3.7	6.5	14.7	23.6	39.1	60.3	83.0	110.9	138.4	172.3	198.2	220.3	243.6	262.4	281.0	374.8
2001	3.7	5.0	15.1	25.5	36.2	63.0	92.0	115.5	145.5	174.5	200.0	223.6	246.3	263.8	282.0	349.8

2002	4.7	7.3	12.8	24.3	38.3	54.5	89.1	113.4	141.5	171.3	199.7	223.3	245.9	262.7	281.3	346.5
2003	4.1	8.1	14.6	26.3	42.3	63.6	93.1	115.0	141.1	168.2	196.9	224.0	248.3	262.9	278.9	338.2
2004	5.3	6.9	14.3	23.2	37.9	57.2	80.2	108.3	139.2	168.0	195.2	218.1	245.7	262.5	279.8	339.4
2005	2.9	7.3	13.6	23.6	36.5	51.8	78.2	106.0	138.2	169.2	194.5	219.3	242.7	259.9	277.2	344.7
2006	3.4	6.6	13.6	25.1	38.7	56.4	81.6	105.1	134.7	166.2	192.7	221.8	242.3	257.5	276.8	348.3
2007	3.4	7.8	14.0	24.0	37.9	55.6	77.6	110.8	140.6	170.1	195.2	222.0	242.9	261.5	279.7	356.9
2008	3.5	8.4	14.0	22.0	43.7	63.5	93.1	115.3	143.8	170.0	196.3	222.4	245.0	261.7	278.8	362.7
2009	3.4	7.0	16.0	23.8	40.8	63.3	79.5	110.8	138.8	166.2	193.4	221.7	244.4	263.5	282.4	345.4
2010	3.8	7.7	11.6	25.6	37.9	62.0	92.2	109.1	139.1	166.0	194.4	221.3	244.4	262.7	281.6	336.5
2011		7.4	10.8	23.5	41.7	53.6	86.6	109.3	135.9	168.6	196.0	222.2	244.4	262.3	282.0	330.6
2012	3.5	6.4	15.5	22.9	38.6	67.6	85.6	114.3	143.4	169.1	197.7	219.7	246.6	262.3	280.2	336.7
2013	2.8	7.0	13.9	25.2	36.1	58.3	90.8	109.1	141.3	170.8	198.6	224.2	247.1	263.5	281.6	335.9
2014	3.0	8.0	10.5	25.9	35.9	62.4	94.0	116.2	143.5	171.2	200.2	223.4	244.4	262.2	281.0	342.4
2015		9.8	15.1	19.9	43.3	60.5	89.9	111.6	144.8	174.0	201.1	225.5	247.7	264.0	283.5	340.0

Table 3. WBFT Task I landings.

Year	Task I	Year	Task I
1950	1 017	1981	5 770
1951	1 123	1982	1 660
1952	694	1983	2 554
1953	1 084	1984	2 301
1954	823	1985	2 680
1955	544	1986	2 329
1956	247	1987	2 504
1957	546	1988	2 902
1958	1 207	1989	2 766
1959	1 649	1990	2 782
1960	1 032	1991	2 929
1961	1 620	1992	2 296
1962	5 799	1993	2 384
1963	13 838	1994	2 113
1964	18 608	1995	2 448
1965	14 167	1996	2 512
1966	8 080	1997	2 334
1967	5 940	1998	2 657
1968	3 176	1999	2 772
1969	3 012	2000	2 775
1970	5 466	2001	2 784
1971	6 591	2002	3 319
1972	3 948	2003	2 305
1973	3 871	2004	2 125
1974	5 390	2005	1 756
1975	5 072	2006	1 811
1976	5 880	2007	1 638
1977	6 695	2008	2 000
1978	5 765	2009	1 980
1979	6 255	2010	1 857
1980	5 784	2011	2 007
		2012	1 754
		2013	1 482
		2014	1 626
		2015	1 842

Table 4. Configuration of various ASAP runs with the data from the 2014 Assessment.

	Run 1	***Run 2***	***Run 3***	***Run 4***	***Run 5***
Objective function	2411.69	2500.09	2386.93	2397.98	2424.49
Phase Fmult year 1	1	1	1	1	1
Phase Fmult devs	3	3	3	3	3
Phase R devs	3	3	3	3	3
Phase N year 1	2	2	2	2	2
Phase Q year 1	1	1	1	1	1
Phase Q devs	-1	-1	-1	-1	-1
Phase S/R relationships	1	1	1	1	1
Phase steepness	-4	-4	-4	-4	-4
R CV	2	2	0.9	0.9	0.9
Lambda for index	1	1	1	1	1
Catch total CV	0.01	0.01	0.01	0.01	0.01
Catch EFSS	50	50	50	50	50
Lambda Fmult year 1	0	0	0	0	0
CV Fmult year 1	0.9	0.9	0.9	0.9	0.9
Lambda Fmult devs	0	0	0.1	1	10
CV Fmult devs	0.9	0.9	0.9	0.9	0.9
Lambda N year 1	0	0	0	0	0
CV N year 1	0.9	0.9	0.9	0.9	0.9
Lambda R devs	1	1	1	1	1
Lambda Q year 1	0	1	0	0	0
CV Q index	0.9	0.9	0.9	0.9	0.9
Lambda Q devs	0	0	0	0	0
CV Q devs	0.3	0.3	0.3	0.3	0.3
Lambda Dev Steep	0	0	0	0	0
CF Dev Steep	0.9	0.9	0.9	0.9	0.9
Lambda dev Unexpl	0	0	0	0	0
CV dev Unexpl	0.9	0.9	0.9	0.9	0.9

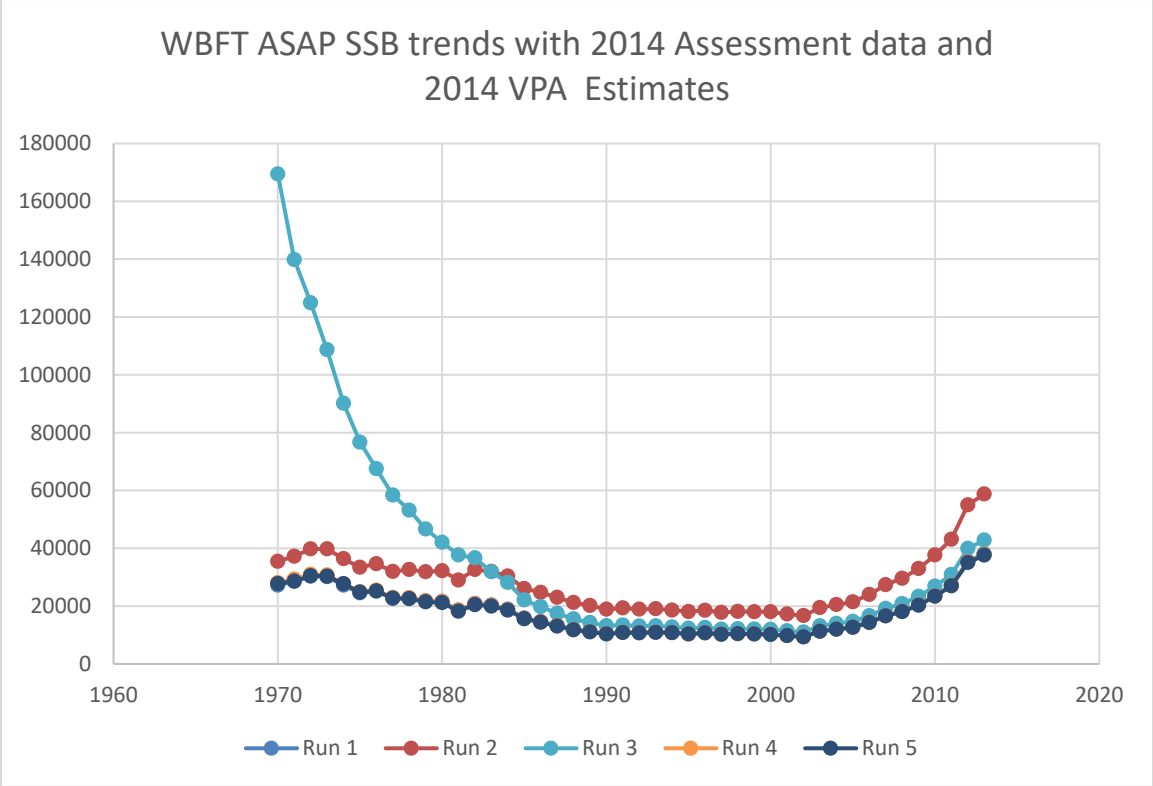

Figure 1. WBFT SSB trends with 2014 Assessment data and 2014 VPA estimates.

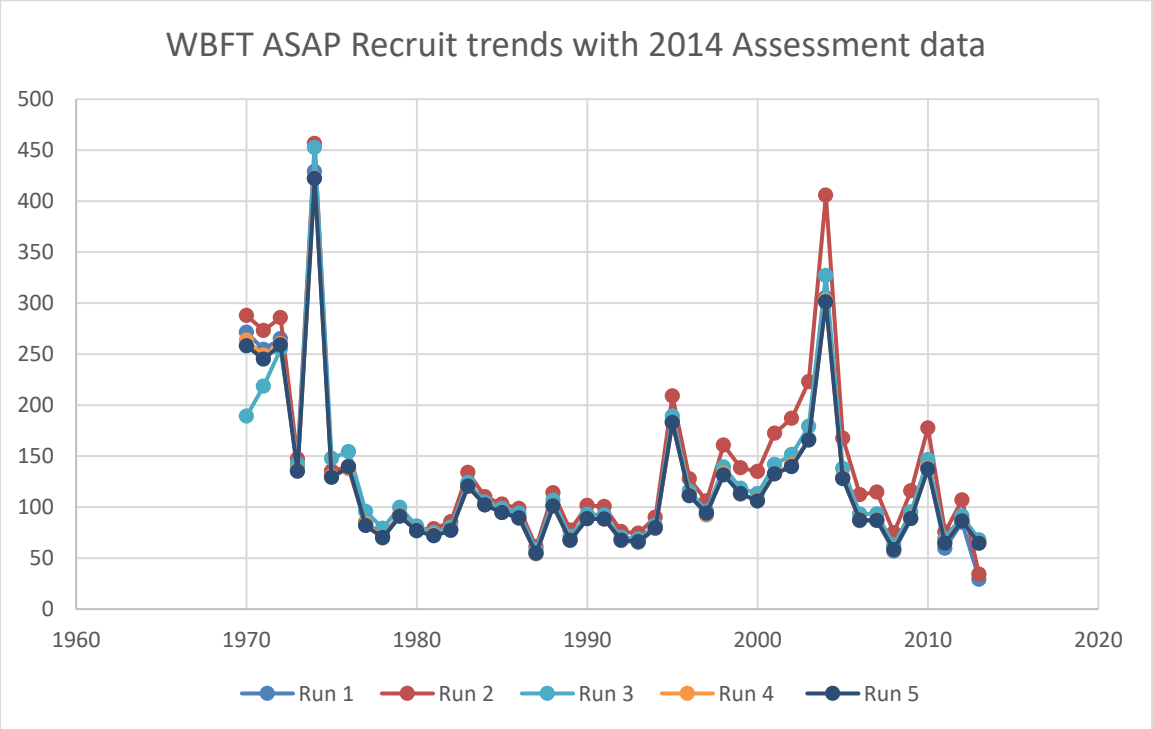

Figure 2. WBFT Recruitment estimates from various ASAP runs with data from the 2014 assessment.

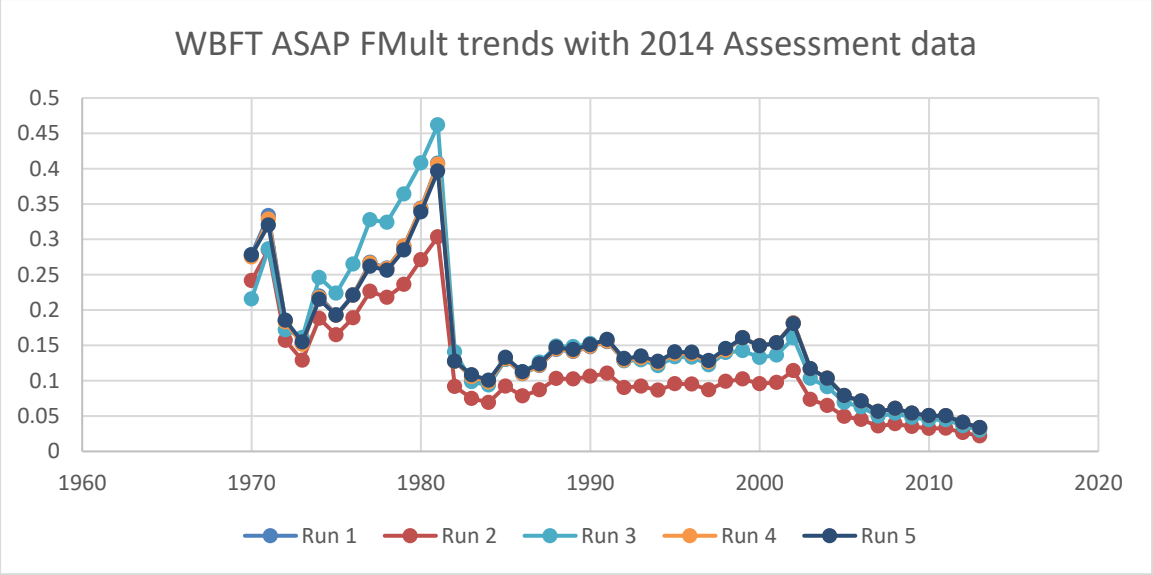

Figure 3. WBFT FMult estimates from various ASAP runs with data from the 2014 assessment.

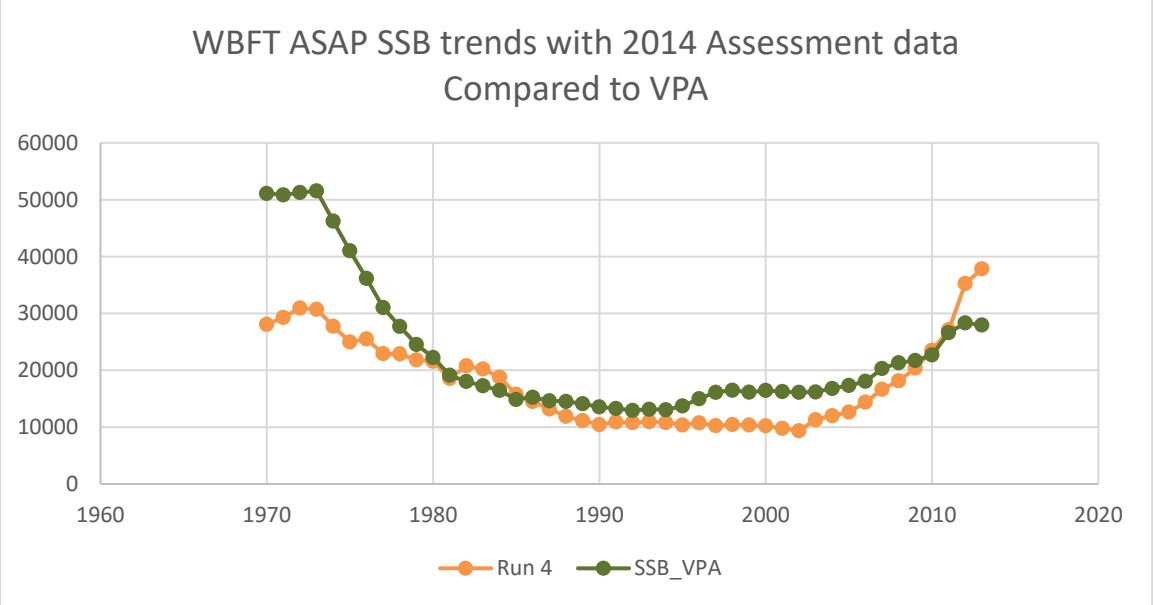

Figure 4. WBFT Comparison of SSB estimates from ASAP with the 2014 VPA results.

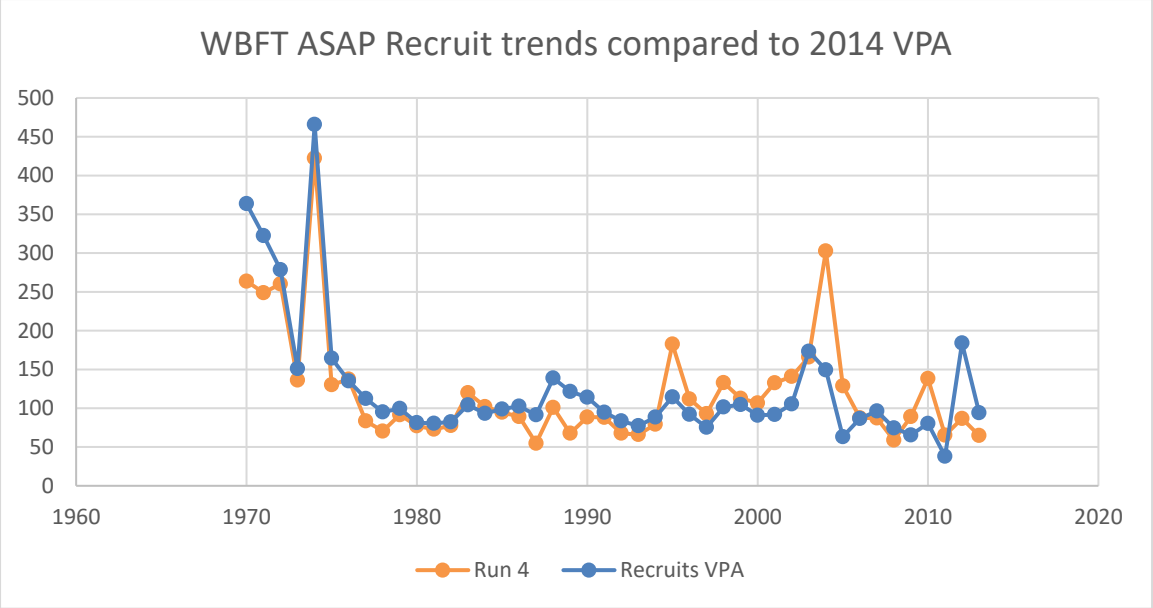

Figure 5. WBFT Recruitment estimates from ASAP and from the 2014 VPA.

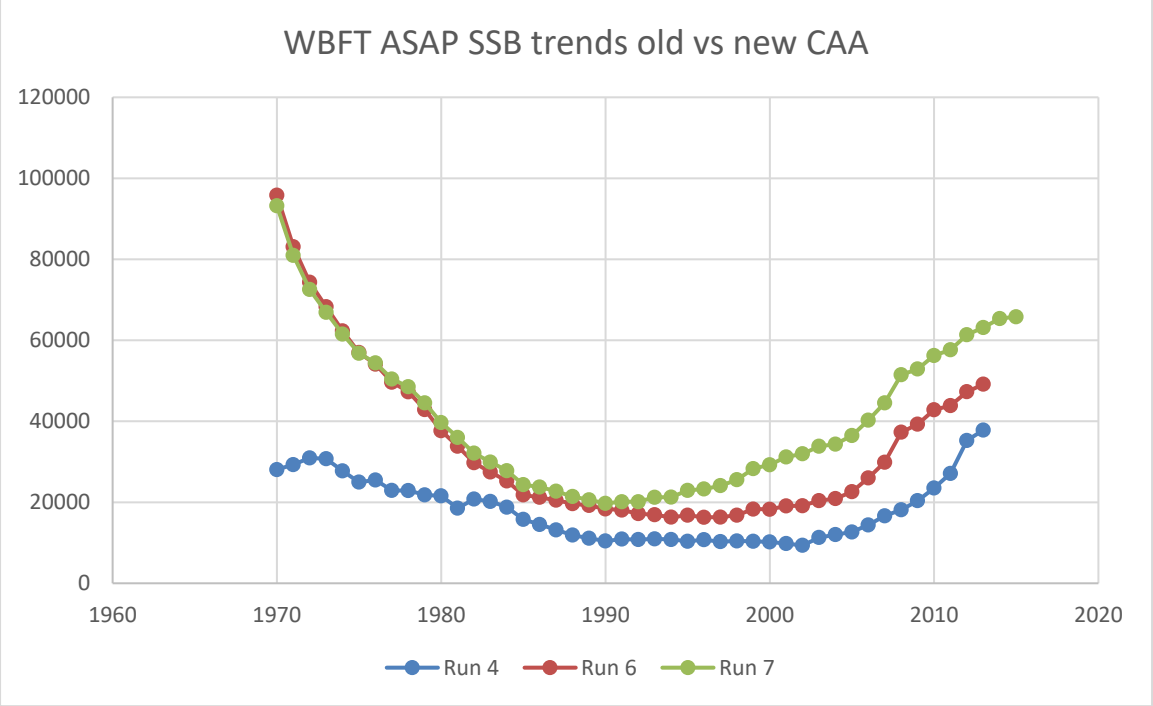

Figure 6. WBFT ASAP SSB trends with new CAA.

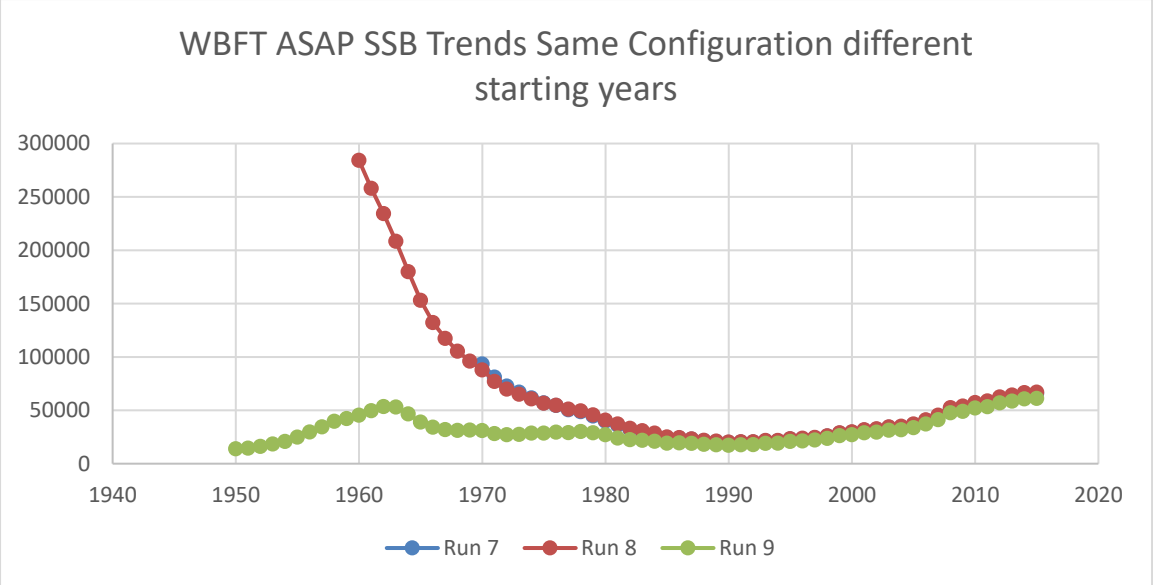

Figure 7. WBFT SSB trends from ASAP with different starting years.

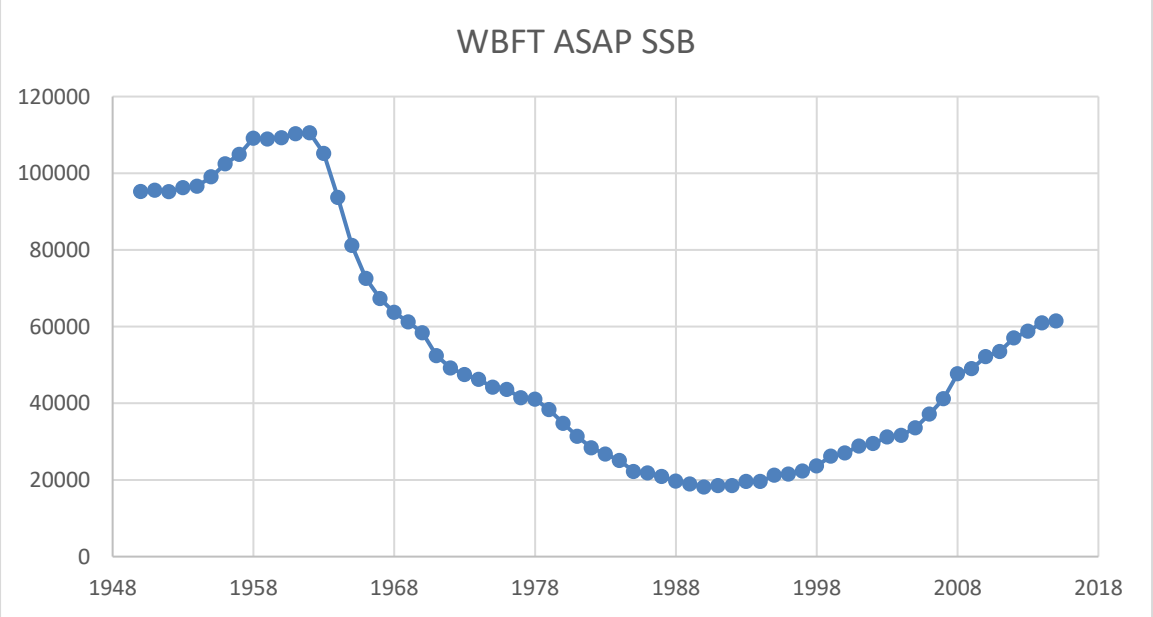

Figure 8. West Atlantic Bluefin tuna trend in ASAP SSB over time.

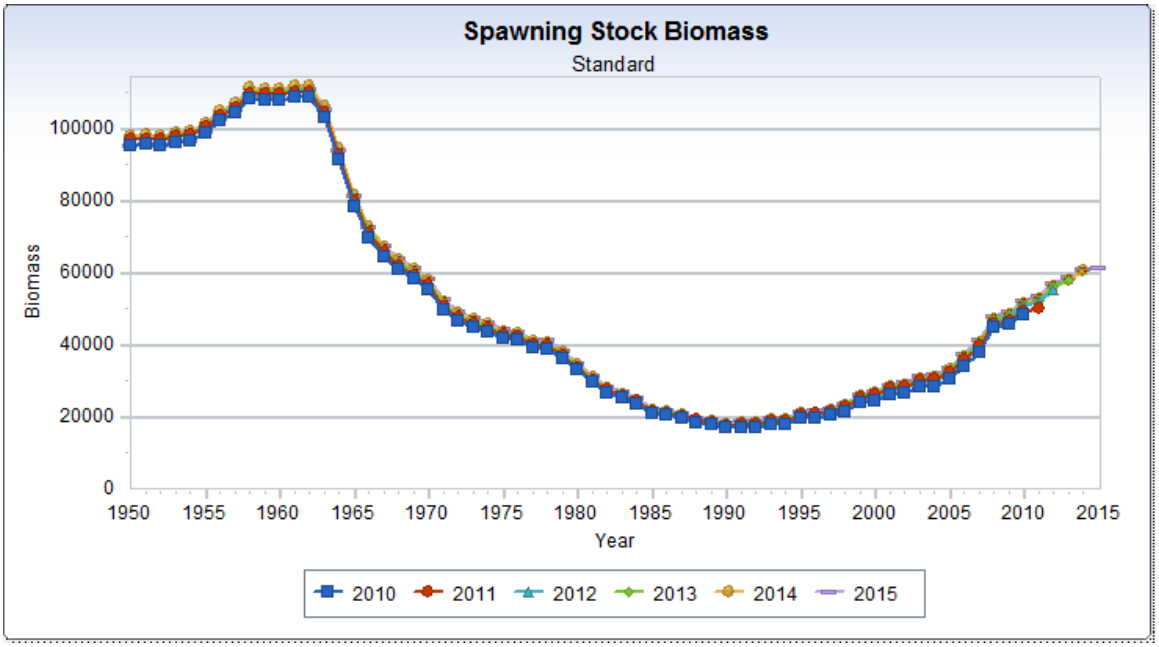

Figure 9. West Atlantic bluefin tuna ASAP retrospective analysis.

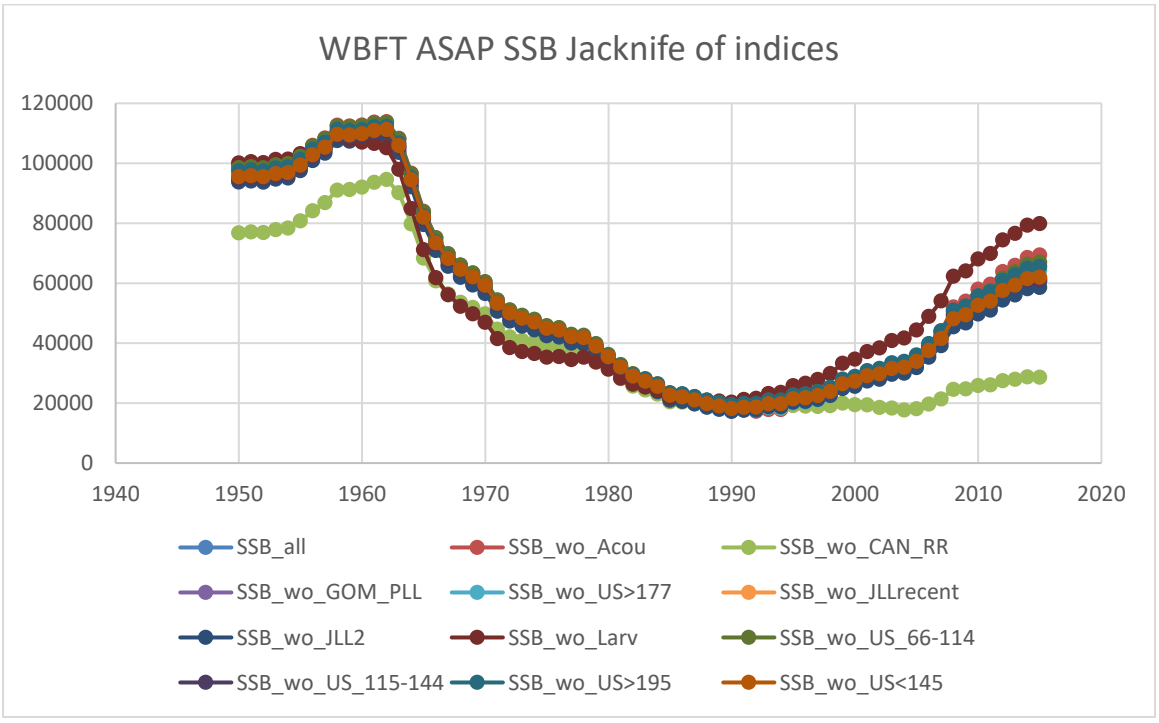

Figure 10. West Atlantic bluefin tuna ASAP SSB results when indices are removed one at a time.

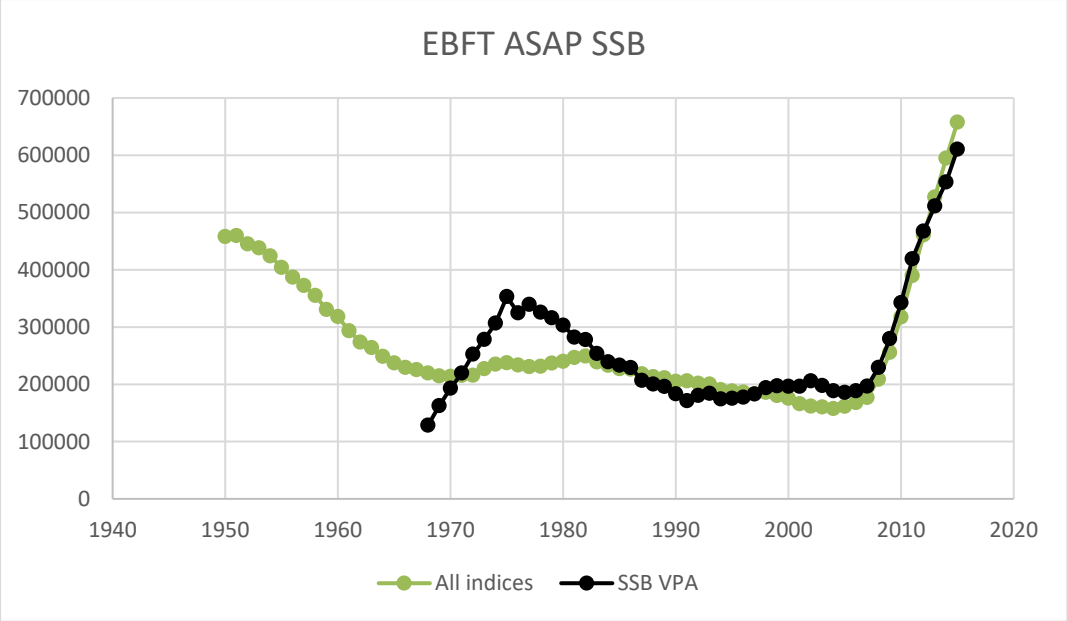

Figure 11. East Atlantic + Mediterranean bluefin tuna ASAP SSB trends compared with the VPA.

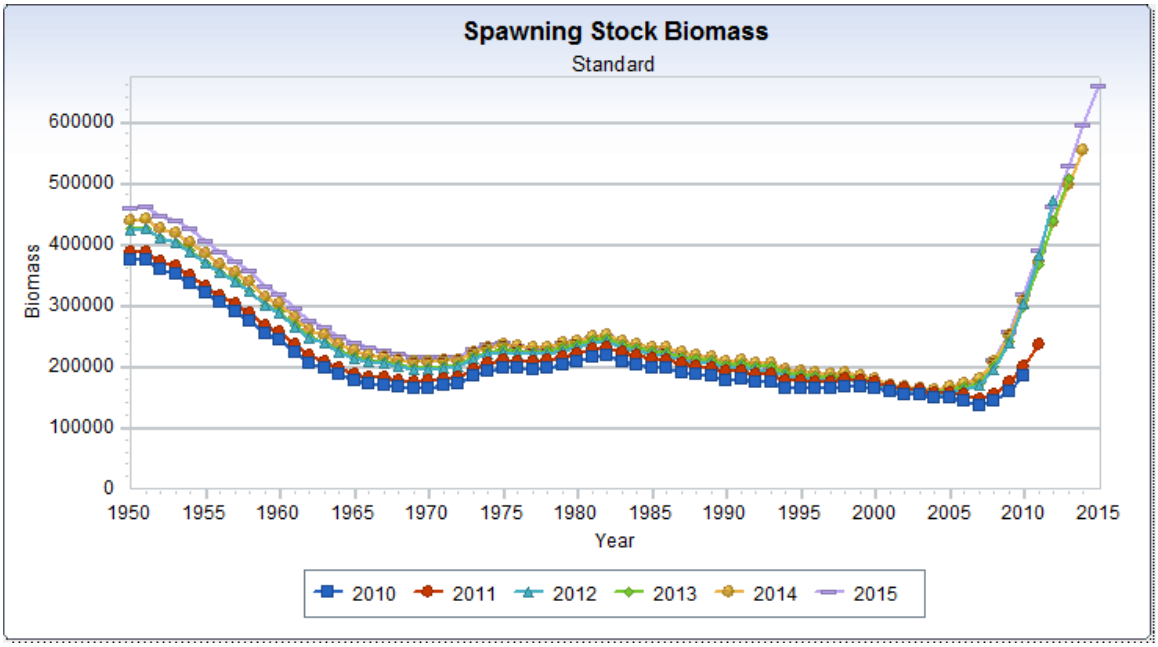

Figure 12. East Atlantic + Mediterranean bluefin tuna ASAP retrospective analysis.

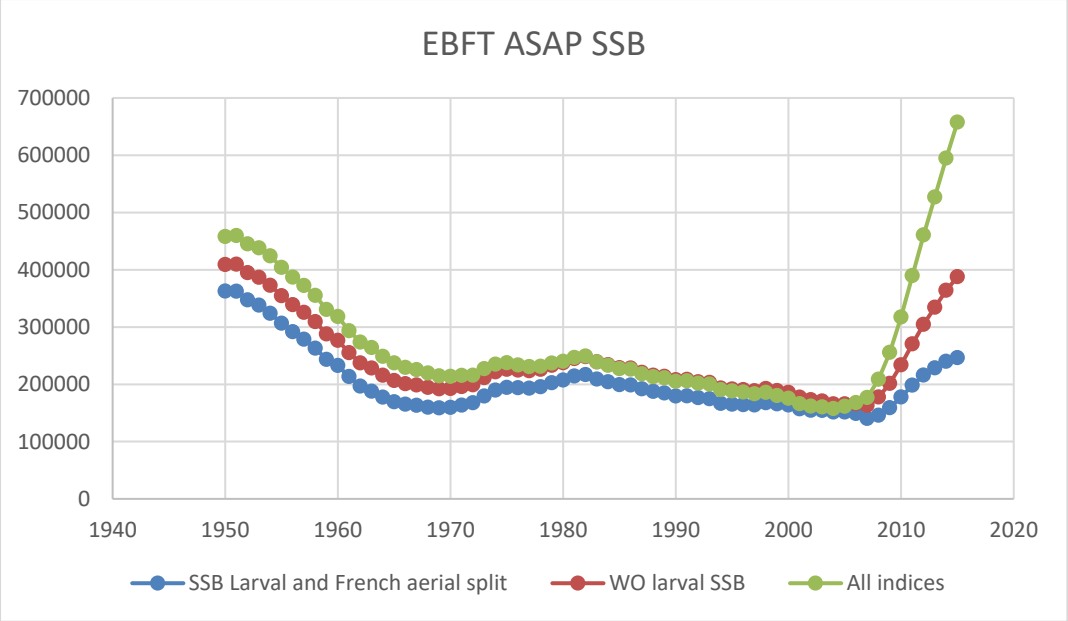

Figure 13. East Atlantic + Mediterranean bluefin tuna SSB estimates when removing or spliting indices.

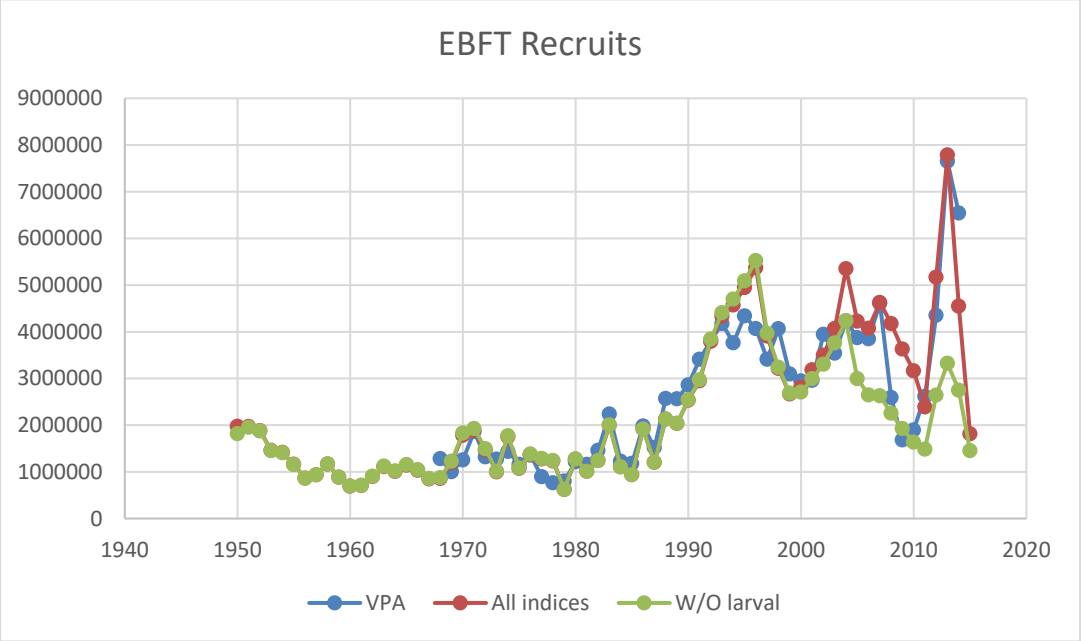

Figure 14. East Atlantic + Mediterranean bluefin tuna ASAP recruitment estimates.