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REVIEW AGEING PROTOCOL FOR ATLANTIC NORTHEN ALBACORE (*THUNNUS ALALUNGA*)

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SUMMARY

Ageing protocols for albacore tuna were revised and compared to the CAA produce in the last assessment of 2009. In prior assessments, an application of the Kimura-Chikuni method was used with quarterly mean size at age estimates and associated expected variance at size by age. These estimates are based on the deterministic growth function adopted in 2009. This document describes the application of the algorithms for ageing the 2011 catch at size matrices and compared to estimates of the 2009.

RÉSUMÉ

Les protocoles de détermination de l'âge pour le germon ont été révisés et comparés à la prise par âge (CAA) produite lors de la dernière évaluation de 2009. Dans des évaluations antérieures, on a appliqué la méthode de Kimura-Chikuni avec des estimations de la moyenne trimestrielle des tailles par âge et la variance de taille par âge escomptée associée. Ces estimations se basent sur la fonction de croissance déterministe adoptée en 2009. Le présent document décrit l'application des algorithmes pour déterminer l'âge des matrices de prise par taille de 2011 par rapport aux estimations de 2009.

RESUMEN

Se revisaron los protocolos para la determinación de la edad del atún blanco y se compararon con la CAA realizada en la última evaluación, en 2009. En evaluaciones anteriores, se utilizó una aplicación del método Kimura-Chikuni con estimaciones trimestrales de la talla media por edad y con la varianza de talla por edad prevista asociada. Estas estimaciones se basan en la función de crecimiento determinista adoptada en 2009. Este documento describe la aplicación de los algoritmos para la determinación de la edad de las matrices de captura por talla de 2011 y compararlas con las estimaciones de 2009.

KEYWORDS

Albacore, Ageing, Size at age, Growth

1. Introduction

Northern albacore tuna is one of the major temperate tuna species targeted by several fleets in the Atlantic. Age structure base models require the input of the catch at age (CAA) matrix for stock evaluation. CAA is estimated from the Catch-at-size (CAS) matrix, assuming a constant specific size at age relationship, since there is not sufficient age sampling to generate Age length keys by year (ALK). Since prior assessments it has been recommended applying the Kimura-Chikuni algorithm (Kimura and Chikuni, 1987) with quarterly age-size estimates derived from the Bard's growth model (Bard, 1981) with estimates of variance of size at age inferred from the Multifan runs. During the data preparatory meeting (Anon 2013) a preliminary CAA matrix was presented. However in view of significant differences comparing with the CAA from the prior assessment (2009), it was requested a review of the protocol and algorithms and a report on the sources of differences. This manuscript summarizes the request results.

2. Materials and Methods

The north Atlantic albacore growth by Bard (1981) follows a von Bertalanffy growth model with Linf = 124.74 cm fork length, k = 0.23, to = -0.9892. Following the recommendations from prior assessments the growth was modeled by annual quarters (Jan-Mar, Apr-Jun, July-Sep and Oct-Dec) with birth schedule at the beginning of

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the 2nd quarter (Apr). **Table 1** is the matrix of mean size at age and variance (sigma) of size at age by age and calendar quarter adopted in 2009 stock assessment (Anonymous, 2010). **Figure 1** shows the estimated mean size at size adopted by the WG in 2009 (MLAA) and the corresponding predicted size by Bard's growth model. There are some differences.

The Catch-at-Size input file for 2011 included some updates and new in Task II Sz/CAS submitted by CPCs since last assessment. But in general overall there are minor changes when compare CAS 2009 vs. CAS 2011. **Figure 2** shows the differences in total numbers and **Figure 3** by year-quarter. The algorithms of Kimura-Chikuni (KC) have been updated to R by the authors, ageing function and the script for ageing the CAS is provided in **Appendix 1**. Ageing was applied to the CAS matrix for sizes 40 to 150 FL cm (150 represent a plus size group, e.g. integrating over 150 cm fish). Because the MLAA already reflect the birth correction (e.g. smallest fish are in the calendar quarter 2) not modifications were done in the CAS by calendar. In the ageing algorithm, the solution cut-off value (epsilon) was set to 1 10E-5. A test evaluated different values of epsilon from 0.1 up to 1 10E-8. The partial CAA use the same fisheries definition as in 2009 (Anonymous, 2010).

3. Results and Discussion

Initial results of the CAA 2013 using the KC program shows large differences compared to the CAA produce in 2009, particularly in the distributions by age and year (**Figure 4**). Four potential sources were addressed in order to identify the main differences between 2009 CAA and 2013 CAA.

a) Input CAS. The comparison indicates very small differences in the input CAS. From 1975 to 2007, the total number of fish in CAS decreased by 114,379 fish (0.08%) compare to 2007 input CAS. Main difference in 2000, due to a re-classification of some size samples from the Venezuela fleets. Other differences in 2007 (updates of the CPCs for latest year), and minor ones in 2004-06, 1986-87 and 1990-92. But overall, the CAS by Fleet and Quarter is very similar between the 2007 and current assessment. In conclusion, these differences in CAS do not explain the differences on CAA results.

b) Check of the input Probability Mean Length-at-age MLAA. The Mean size at age and the variance (input as CV) used in 2013 are the same as of 2007, as indicated in table 8 of the 2009 report, including ages 0 to 15, and from 40 to 150 cm (expanded as in 2009, the upper size limit was 130 cm FL). Also, noted that the MLAA by quarter are close but not exactly the same as the predicted by the growth model adopted in 2009, Bard [Linf 124.74, k 0.23, and t0 -0.9892], estimated at the mid-point of each quarter (**Figure 1**).

Important however, to note that already in the MLAA it is assume that fish are born I Q2, thus the expected mean size of Q1 represents the largest fish born in the prior year (young of the year), and for older ages is the largest expected mean size for each age group. This implies that the fish are born in the mid-point of the 2nd calendar quarter (e.g. May 15th).

c) The KC algorithm settings. Already in 2009 they were identify some issues with the solutions provided by the algorithm KC (SCRS/2009/102). The recommendations from that study were: include age 0 in the CAA estimation and MLAA probability matrix, include up to age 15 at least for NALB, and decrease the cut-off value (epsilon) of the search algorithm. These recommendations were evaluated and implemented in the KC 2013 algorithms. In 2013, MLAA were extended from sizes 40 to 150 cm FL, and ages 0 to 15. It was also used the cumulative frequency probability for the 1st bin size (40) and check that sum of probabilities at size by age were 1 or very close to 1 (all above 0.98). A test for the epsilon (or cut-off value for the algorithm solution) was evaluated. Briefly, epsilon values from 0.1 to 1E-8 were evaluated for the same input CAS data. It was considered the trial with 1E-8 as base case. Results of the epsilon test are shown in **Figure 5**. The results indicated that substantial differences are observed if epsilon is set above 1 10E-4. Based on the results it was adopted 1 10E-5 as epsilon setting for the algorithms, as higher values greatly increase the computing time with minor gains in precision. The results indicate that epsilons of 1E-5 or lower produce stable results with absolute differences among year-age distribution of less that 0.01% on total. Also this test confirm that the total number of fish in the CAS input was the same as the total fish in the CAA output, for all epsilon values. Inherently, the variations in age-distributions associated with epsilon (values of 1E-4 or above) were greater with the ages with highest number of fish. It is recommended using at least an epsilon value of 1E-5 with the KC algorithm. The differences observed in relation with epsilon could partially explain differences in CAA 2009 and 2013 versions.

d) Other main item found to account for the differences in CAA, was the setting of the quarter of the year CAS input records. It has been confirmed that in 2009, the calendar quarter were modified such the CAS was introduced with birth quarter adjusted such Jan-Mar was designated Q4, Apr-Jun Q1, Jul-Sep Q2, and Oct-Dec

Q3. When this modification was introduced with the 2013 CAS input file, the CAA output is close to the values estimated in 2009 (**Figure 6**), note that age 1 it was age 0 + age 1 in 2009, and age 8 is a plus group including ages 8 to 15. The same results were seen comparing directly with the input VPA-2box data file.

In conclusion, the differences in CAA between 2009 and 2013 seem mostly explained by the definition of the quarter use as input in the KC algorithm. Because the actual total numbers of fish by year did not change, the "cohort year" was not modified (e.g. assigning size samples of Jan-Mar to the prior calendar year). The epsilon and size range could also explain some of the differences, but in less proportion. However, there are still some differences not accounted for. Therefore it was possible to match CAA total by year, but not exactly by age group. It was confirmed that using CAS input with quarter birth (e.g. reassigning Jan-Mar samples to Q4), and 0 to 15 ages, the CAA estimated is similar to the 2009 CAA used as input for the VPA in 2009.

However, it is noted, that using the correction of MLAA for quarter 1 (**Table 1**, **Figure 1**) plus adjusting the CAS input to Quarter birth is doing "double" the correction and thus incorrect, for generating CAA with the KC algorithm. The explanation is that because already the MLAA by quarter are indicating that for example, a fish 42 cm sampled in February is most likely (e.g. high probability) of being assigned age 0, while a fish caught in August also 42 cm likely will be assigned as Age 0. IF besides this MLAA matrix, the date of the samples are adjusted, e. g. the same fish caught in August would be "moved" to May quarter and it will incorrectly assigned to age 1 (**Table 2**).

Therefore the recommendation is to continue using the MLAA as developed (noticing however, that they don't match exactly with the growth model adopted), use the Calendar quarter and inform the VPA model that the month of birth for N-ALB is 3, enter CAA, Catch, WAA, PCAA, maturity, etc. in calendar year Jan-Dec in all cases. Following these recommendations, the 2013 CAA for north Albacore ages 0 – 15+ is presented in **Table 3** and **Figure 7**, corresponding PCAA for the same fleet definition of 2009 are show in **Table 4**. Cumulative and density frequency PCAA distribution by VPA Fleet definitions are shown in **Figure 8**. Notice that for 2007-08 there is limited information for the US-LL fleet.

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Table 1. Mean length at age (MLAA) and associated variance (sigma) by age and calendar quarter for the northern albacore stock based on the Bard's growth model.

	age:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Quarter 1	mean	44.46	59.75	72.06	81.96	89.93	96.35	101.52	105.68	109.03	111.72	113.89	115.63	117.04	118.17	119.08	119.81
	sigma	2.73	3.05	3.31	3.54	3.73	3.89	4.03	4.14	4.24	4.32	4.39	4.45	4.5	4.54	4.58	4.61
Quarter 2	mean	30.61	48.6	63.08	74.74	84.12	91.67	97.75	102.65	106.58	109.75	112.31	114.36	116.01	117.35	118.42	119.28
	sigma	2.73	3.05	3.31	3.54	3.73	3.89	4.03	4.14	4.24	4.32	4.39	4.45	4.5	4.54	4.58	4.61
Quarter 3	mean	35.48	52.52	66.24	77.28	86.16	93.32	99.08	103.71	107.44	110.45	112.86	114.81	116.37	117.64	118.65	119.47
	sigma	2.73	3.05	3.31	3.54	3.73	3.89	4.03	4.14	4.24	4.32	4.39	4.45	4.5	4.54	4.58	4.61
Quarter 4	mean	40.09	56.23	69.22	79.68	88.1	94.88	100.33	104.72	108.26	111.1	113.39	115.23	116.72	117.91	118.87	119.64
	sigma	2.73	3.05	3.31	3.54	3.73	3.89	4.03	4.14	4.24	4.32	4.39	4.45	4.5	4.54	4.58	4.61

Table 2. Probability of age assignment for a fish (albacore north) of size 42 cm FL, sampled during the year.

Cal Qtr	Month	Age0	Age1	Age2	Age3	Age4
Q1	Jan Mar	1.0000	0.0000	0.0000	0.0000	0.0000
Q2	Apr Jun	0.0062	0.9938	0.0000	0.0000	0.0000
Q3	Jul Sep	0.9848	0.0152	0.0000	0.0000	0.0000
Q4	Oct Dec	1.0000	0.0000	0.0000	0.0000	0.0000

Table 3. Estimated CAA north ALB stock 2013. CAS input using the calendar quarter definition, see text for details.

Year	Age_0	Age_1	Age_2	Age_3	Age_4	Age_5	Age_6	Age_7	Age_8	Age_9	Age_10	Age_11	Age_12	Age_13	Age_14	Age_15
1975	11762	477040	1476729	1403321	428884	171347	106435	77139	50028	30553	19154	12770	9125	6990	5821	5384
1976	7530	1069458	2162027	1050125	734451	409380	235539	131192	70741	37873	21074	12623	8260	5891	4580	3802
1977	5299	555836	2295220	1253662	480070	345543	233630	130969	69214	36313	20013	11988	7887	5679	4475	3793
1978	14635	2261986	2459274	1046468	397258	223112	163395	97608	50326	25154	13528	8184	5575	4200	3447	2985
1979	45142	864989	2256061	1600921	578962	252339	111964	53595	29757	18077	12237	9145	7383	6362	5819	5547
1980	9303	1665186	1626685	1137755	317302	141261	83844	52879	28285	14277	8121	5531	4280	3566	3141	2931
1981	10964	1154142	1537500	865646	319489	106636	65871	48303	32430	21265	14856	11444	9689	8887	8769	9070
1982	2005	319894	1666988	1296928	489193	143015	90754	67652	46081	30448	21267	16469	14132	13100	12969	13389
1983	9570	1078560	1617390	1385847	595854	264005	156535	94804	56040	33308	21337	14865	11154	8945	7718	7082
1984	11181	712085	1189973	864252	345454	230093	178911	129154	81106	48346	30185	21109	16791	14931	15017	16375
1985	16045	1124898	1383716	882822	311614	205586	146087	91034	55884	36403	25997	20103	16387	13817	11990	10694
1986	27579	891420	1603745	1103649	399453	211395	161298	113746	75352	51539	37102	27834	21454	16890	13674	11436
1987	4124	443870	2344578	1265790	258370	70305	44221	32264	22895	16369	12244	9646	7897	6632	5662	4810
1988	7364	1706185	2008752	888535	200526	52503	27662	17821	11903	8054	5764	4397	3518	2901	2445	2085
1989	5973	1134350	1743158	1128427	222753	65682	32296	13930	7266	4296	2711	1842	1354	1067	893	779
1990	59056	1153547	2315708	805352	275168	137548	84106	44853	24794	14460	9042	6039	4330	3354	2811	2498
1991	38468	1316900	1990461	576481	171798	108759	58039	18395	6790	3319	1943	1255	874	654	526	444
1992	14876	1291002	1786160	758447	170381	55855	56253	44180	32214	22228	14734	9825	6813	4971	3845	3105
1993	13948	1127445	1862543	1143178	337904	111711	80885	53347	30386	17238	10497	7008	5162	4166	3659	3448
1994	10297	805023	2200656	735078	219600	83426	57612	40908	25703	16201	11685	10787	11810	14189	18338	24756
1995	41328	1320844	2095899	851623	196786	136202	111908	77394	49039	29669	17975	11303	7515	5324	4127	3505
1996	9581	1461998	2150212	356531	117414	86872	71234	45440	26855	15426	9173	5875	4117	3165	2653	2325
1997	81888	1738879	1637256	692943	159463	64672	45093	32215	21056	12722	7622	4787	3250	2411	1960	1704
1998	5695	1992744	1723723	479018	132889	40962	26861	21014	14643	9354	5869	3807	2628	1953	1574	1353
1999	26218	1831244	1435806	977411	307068	106602	56472	36052	23582	14869	9270	5963	4048	2897	2172	1663
2000	8171	1028336	1628418	883153	213893	72001	104145	95383	51261	21810	9035	4177	2315	1546	1209	1032
2001	3094	512027	816461	706100	279328	142596	122536	72921	32847	13886	6397	3362	2022	1379	1060	878
2002	16130	879000	407395	273302	291221	185059	135902	83186	42816	21271	11142	6356	4007	2852	2376	2272
2003	12588	1771368	648364	400566	241757	145376	119504	75653	38875	18955	9806	5630	3598	2522	1919	1542
2004	13415	875023	1342599	547537	184744	115484	81148	49871	28340	16134	9784	6457	4646	3621	3048	2724
2005	31342	1321635	1633779	1016641	312194	132383	87553	49154	25381	13156	7155	4192	2704	1949	1598	1460
2006	23027	1286098	1952190	1084087	375769	92750	54849	35441	20727	11918	7073	4458	3040	2251	1805	1529
2007	8854	343185	1078407	805441	155363	56236	40829	28330	16979	9417	5341	3297	2313	1936	2103	2666
2008	16467	704412	1004616	509434	225008	49382	32392	22546	13637	8572	6073	4914	4417	4295	4527	5129
2009	23572	265416	658744	526662	163547	41789	22187	14519	9770	7587	6385	5427	4651	4052	3603	3262
2010	28197	576691	1207936	393936	166822	54744	34206	30357	21390	13669	8968	6381	4947	4096	3550	3138
2011	17518	995667	755105	641496	114835	59184	39787	28237	18332	11205	7156	5026	3902	3291	2963	2782

Table 4. Estimated P-CAA north ALB 2013. Fleet definition as in 2009 SA VPA.

Fleet	Year	Age_01	Age_2	Age_3	Age_4	Age_5	Age_6	Age_7	Age_8P
BBEspCt	1975	164644	419584	420164	98189	15550	2126	506	257
	1976	245645	368757	412840	250413	72452	14559	2921	784
	1977	99736	365830	366475	81882	36686	22086	12136	14031
	1978	882706	270310	292649	146101	33945	10144	1792	1057
	1979	347042	720574	691006	139587	18595	4490	1110	716
	1980	761974	471446	696652	167894	21753	3070	910	2077
	1981	549996	484755	446996	147667	18184	1504	176	123
	1982	88805	697082	711699	202783	18032	1588	312	136
	1983	798647	567992	707035	262062	40282	8086	1248	486
	1984	210216	154599	322712	94367	9882	1650	449	180
	1985	569722	502217	381277	85103	11234	2687	633	354
	1986	404083	546248	621377	174909	22339	3586	764	355
	1987	163614	1275595	769512	113514	9922	696	74	31
	1988	1094739	973564	461982	61833	6189	1654	1272	1966
	1989	676407	640433	596274	124575	18672	3817	1085	1122
	1990	780854	881820	378315	134529	26754	5682	1937	1240
	1991	674828	597409	145379	36478	3319	253	46	42
	1992	550220	478597	328368	85652	10086	1123	260	114
	1993	617271	529074	332041	47830	2492	227	44	39
	1994	411038	618648	271324	52964	3678	238	25	14
	1995	495978	582132	320409	35810	1504	76	10	5
	1996	592657	861426	117884	22564	1843	123	23	14
	1997	739975	203485	359359	59169	9183	4770	2737	3782
	1998	1183924	389138	105763	20271	2147	332	130	68
	1999	887384	243396	143550	50164	14966	4019	953	474
	2000	680873	471694	432774	84679	8708	1430	420	262
	2001	154246	157519	150712	20956	6666	3859	1681	1475
	2002	290408	26156	97128	76716	20036	6364	2056	1103
	2003	997234	215345	89703	53349	14095	5190	2027	1042
	2004	334361	560790	222286	45788	6385	1376	694	703
	2005	171718	275788	495355	146918	14761	2259	553	186
	2006	388660	883008	490489	174484	13575	702	180	168
	2007	84218	292404	466349	71741	16494	5673	1340	471
	2008	252156	347086	236321	90644	7599	679	178	81
	2009	8162	83175	272261	94467	11370	1260	202	116
	2010	74583	378994	145267	80963	16022	1720	195	59
	2011	712970	80051	96619	12435	7234	3114	910	924
LL_CTP	1975	420	16916	85491	100807	70048	52527	39557	70432
	1976	3427	31276	119100	191679	175832	122648	72688	89630
	1977	2982	31123	112396	148848	158333	119101	72147	90115
	1978	671	6171	49563	81046	109485	98684	63262	62261
	1979	3267	21343	77873	127187	87308	43877	23413	30194
	1980	4389	22307	39290	77662	85573	61481	41003	49889
	1981	7099	19246	48518	63514	40079	34099	30369	84179
	1982	7598	56548	91897	76961	74802	59190	44402	127798
	1983	7387	41275	107534	158871	144446	103494	67961	129093
	1984	19953	49520	106066	131862	133997	107568	72037	151522
	1985	5291	29818	94235	132805	142552	106379	67853	159409
	1986	8816	41104	135985	168911	163014	134019	95559	226479
	1987	46730	62325	76277	59763	36610	30002	23679	72798
	1988	14908	19883	24334	19066	11679	9571	7554	23224
	1989	758	35	10484	16456	26440	16144	4656	1372
	1990	0	33	11350	21468	32741	18430	4761	4312
	1991	0	1551	67504	50586	80786	44271	10651	5416
	1992	0	0	325	2032	1500	4493	10817	56610
	1993	1508	11101	89522	90610	66245	43790	27461	39869
	1994	4598	24000	31213	31500	31943	25205	18263	91171
	1995	7161	8341	65311	70052	51806	30460	15270	14682
	1996	8318	4093	13435	25910	47486	40298	24386	34235
	1997	40	2802	73500	49291	21423	16736	12591	21597
	1998	12	2044	73043	42801	18070	13580	10998	22441
	1999	22	3818	136399	79927	33744	25356	20537	41903
	2000	0	274	4183	2517	17114	67867	71221	63525
	2001	69	1228	43814	53102	35565	48581	30396	20041
	2002	1	994	11334	21802	51511	53212	33527	34600
	2003	212	1323	13890	41509	51863	51089	33984	31687
	2004	241	5296	25067	36593	49764	39428	24300	35911
	2005	23	2600	9909	23713	29905	25974	16983	19473
	2006	200	5346	10521	16945	22535	23258	16736	22416
	2007	3	526	3503	3774	7257	12091	11294	17995
	2008	14	499	1380	1645	3055	5381	5940	21914
	2009	0	16	442	1580	2807	3517	3038	18610
	2010	0	0	55	686	4453	11177	13431	29709
	2011	1489	0	15	807	4787	12173	14059	21984
LL_JPN	1975	91	2564	12168	21105	17645	9667	4813	7381
	1976	521	2637	13755	23588	19147	10303	4521	4303
	1977	375	3533	12844	14218	10556	5375	2230	1895
	1978	518	3515	9786	8862	5545	2907	1474	1822
	1979	505	6308	20295	24783	13717	7335	3445	2887
	1980	506	5300	17740	19281	11668	6450	3121	3170
	1981	2204	12733	26924	28228	17258	11110	6129	8039
	1982	666	1213	11087	14277	8673	5217	2680	3241
	1983	1087	6402	27651	18395	11147	6030	2912	3010
	1984	1400	4075	4758	5649	6231	4285	2583	4320
	1985	71	1088	8105	11802	9592	7018	4019	4429
	1986	65	845	4326	6332	4824	3486	2030	3180
	1987	16	964	4204	5037	5146	3712	2427	4024
	1988	63	2084	8646	10803	8298	5140	2883	3336
	1989	118	4156	9339	10065	8320	4831	2566	4262
	1990	144	2675	8446	11356	9258	5373	2613	2624
	1991	1546	4613	11306	11828	6132	3695	2128	2744
	1992	1831	4482	4028	6596	5409	2908	1544	2351

	1993	23576	3615	4866	8085	3670	1929	1287	2156
	1994	14898	355	6940	10068	5177	2453	1329	1742
	1995	3306	245	4567	6576	3596	2170	1500	2396
	1996	0	297	6471	8727	4055	2162	1635	3104
	1997	243	1258	3580	3975	2727	2468	1909	4453
	1998	329	1652	4185	4048	2760	2561	2015	4761
	1999	507	4728	7812	8373	3370	1730	996	1642
	2000	792	3726	5948	7504	6213	5087	3081	5573
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	2003	254	1347	6953	8363	6319	4692	3130	5286
	2004	6231	2927	10047	11126	7999	5897	3948	5990
	2005	17298	7319	14509	9849	14783	12593	6696	6384
	2006	402	1584	7082	9355	10225	6065	2935	4305
	2007	452	1628	2467	2474	2606	1875	1433	2614
	2008	48	620	1385	2956	4910	3842	2122	3194
	2009	29	991	1821	2548	3740	2998	1499	1424
	2010	18	443	881	1742	3798	3780	2748	7840
	2011	44	1762	3134	3934	4665	3511	2046	4991
LL_USA	1975	0	0	0	0	0	0	0	0
	1976	0	0	0	0	0	0	0	0
	1977	0	0	0	0	0	0	0	0
	1978	0	0	0	0	0	0	0	0
	1979	0	0	0	0	0	0	0	0
	1980	0	1	12	52	42	39	26	28
	1981	0	0	3	13	10	10	7	7
	1982	1	2	50	210	167	156	104	110
	1983	1	2	40	171	136	126	85	89
	1984	1	3	78	328	261	243	162	172
	1985	1	2	37	158	126	117	78	83
	1986	2	5	117	495	394	367	245	260
	1987	0	29	200	304	436	443	294	344
	1988	0	4	92	408	545	525	400	585
	1989	0	0	35	371	696	544	379	706
	1990	0	4	51	672	1717	1491	977	1613
	1991	3	12	727	1786	2247	2001	1310	1649
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	1993	0	15	490	2988	1766	1207	1058	1955
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	1995	5	14	193	1944	3352	3249	2493	4909
	1996	3	16	180	588	1030	1222	956	1446
	1997	2	11	229	876	1469	1773	1454	2267
	1998	0	3	300	1776	1467	1413	1214	2053
	1999	14	24	220	1588	1702	1616	1349	2223
	2000	0	12	973	2599	1494	1007	700	1043
	2001	0	26	594	2614	2703	1594	894	1338
	2002	1	10	228	1315	1911	1427	837	1213
	2003	0	2	107	727	1359	1170	681	823
	2004	2	4	155	777	1286	1201	833	1177
	2005	0	6	297	980	1091	967	701	1054
	2006	0	2	320	1195	1072	750	550	1049
	2007	0	0	0	0	0	2	8	2595
	2008	0	0	0	0	2	7	18	2515
	2009	67	37	1680	3209	2090	909	604	900
	2010	0	22	423	3601	3496	914	328	591
	2011	0	9	1321	3837	2735	1570	1196	3039
others	1975	154985	405999	430521	153823	61296	41166	32084	61673
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	1977	57069	211189	234388	132835	133679	86268	44228	53192
	1978	52406	17474	42990	72507	64623	49952	30786	47711
	1979	20928	33983	18796	38575	45477	35973	22859	59081
	1980	18338	18982	36951	30657	19938	12254	7727	14905
	1981	61021	68690	48848	45731	28487	18700	11517	23938
	1982	45937	20479	37258	37790	24411	23666	20049	36524
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	1986	19267	35694	11582	14547	17334	18299	14483	24454
	1987	8957	43547	23889	9313	10463	8561	5627	8854
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	1989	96695	367696	107362	14710	8003	6555	5087	12545
	1990	120600	425580	130055	54614	59637	51372	33817	56497
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	1992	307098	728588	209178	44498	35387	46157	30555	37166
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	1994	135776	964915	281311	106615	39406	27910	19950	38193
	1995	107831	616039	216434	56392	74211	75789	58096	106410
	1996	370150	571833	133379	50059	31639	27322	18409	30772
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	1998	418124	894947	133962	31699	12185	8485	6600	11847
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	2000	219294	876991	240757	63605	26078	25222	18818	21018
	2001	236739	362155	319068	163859	83164	60050	34713	30718
	2002	200334	83579	89137	159948	99732	68218	42815	50205
	2003	185184	87744	203468	117847	62520	51123	32788	41733
	2004	40336	94192	140119	68125	44438	31262	19267	30188
	2005	410314	362923	289043	113668	68598	44610	23761	30035
	2006	75007	176620	343615	159031	44388	23755	14962	24794
	2007	36465	181919	182535	61898	26877	20038	13736	19913
	2008	43478	210538	165604	112134	32509	22345	14242	23837
	2009	56038	220512	104756	43717	19758	13033	9036	23603
	2010	142369	189850	76349	47379	23903	16174	13409	27581
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TR_ESPCt	1975	121742	286020	186744	38261	6054	828	141	60
	1976	363486	793310	170042	51963	8115	1179	264	100
	1977	237272	996225	312180	60526	3722	471	134	78
	1978	928135	1074573	400084	83732	9512	1708	293	548

	1979	451921	1340790	456931	41296	4558	1447	437	599
	1980	617484	731497	298363	21341	2280	550	92	63
	1981	396765	703664	244003	32778	2503	425	104	124
	1982	141960	849317	387134	49148	2425	86	5	1
	1983	78878	809653	426774	75250	5480	257	23	7
	1984	195464	711489	304773	33073	2930	294	31	9
	1985	423968	670368	292027	36565	4132	1005	444	297
	1986	438706	883102	297652	30878	3145	1389	600	499
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	1988	499635	751943	313745	91060	15341	3792	1505	1904
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	1990	299493	988169	267928	48958	6648	1499	599	737
	1991	504784	909272	193030	21583	1810	406	109	59
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	1995	747891	889129	244710	26013	1733	163	27	53
	1996	500450	712545	85183	9567	819	108	30	17
	1997	568216	726844	174620	21304	2039	306	74	59
	1998	396049	435939	161765	32293	4332	490	58	12
	1999	440425	444944	214226	44008	10508	3015	877	432
	2000	135548	275722	198517	52989	12393	3531	1143	963
	2001	122879	289120	173725	21593	4270	2058	1509	2279
	2002	404338	293852	64960	21898	6178	2528	1164	1047
	2003	600666	342443	86141	19853	9183	6210	3023	2248
	2004	507105	678982	149251	22170	5563	1953	811	755
	2005	753129	984703	207206	16979	3231	1144	456	459
	2006	844855	885631	232060	14760	954	318	78	71
	2007	230881	601754	150394	15429	2995	1148	518	463
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	2009	224680	353986	145633	17995	2023	468	140	84
	2010	387919	638627	170961	32451	3073	441	245	359
	2011	209321	254396	138009	8516	1099	421	175	231
TR_FRA	1975	46920	345647	268232	16699	754	121	38	22
	1976	331723	765101	81923	8737	638	71	16	8
	1977	163700	687319	215379	41761	2567	328	94	51
	1978	412187	1087231	251397	5011	2	0	0	0
	1979	86470	133063	336019	207533	82683	18841	2330	851
	1980	271798	377153	48746	415	8	0	0	0
	1981	148020	248411	50353	1557	114	24	1	0
	1982	36932	42347	57804	108023	14504	852	100	45
	1983	16317	167493	88287	15567	1134	53	5	1
	1984	66095.578	240587.28	103057.22	11184.17	990.6207	99.36506	10.4557	3.07505
	1985	83897.481	132656.56	57787.953	7236.075	817.1252	199.1382	88.1823	58.4987
	1986	48061.426	96745.933	32609.865	3380.277	345.7104	152.2347	65.6913	54.6247
	1987	28776.825	121073.49	49291.902	8866.715	969.0898	103.5646	22.2285	11.1192
	1988	16356.840	24616.779	10271.255	2981.077	502.2282	124.1674	49.2550	62.3499
	1989	1908.9039	6932.8942	1989.5506	173.5442	8.608103	0.776278	0.26458	0.09571
	1990	11513.653	17427.434	9206.2023	3570.230	794.1058	260.3285	149.452	302.647
	1991								
	1992								
	1993								
	1994								
	1995								
	1996								
	1997								
	1998								
	1999								
	2000								
	2001								
	2002								
	2003	405.98796	160.60826	303.97394	108.4748	37.31032	31.03436	19.5109	25.6085
	2004	161.84079	407.95702	613.28302	164.9936	48.82802	29.37255	18.1990	29.5274
	2005	494.21045	439.64277	321.71926	86.30834	12.25301	5.708348	4.04863	4.00694
	2006	0.0008696	0.0004861	0.0003881	0.000306	0.000242	0.000191	0.00015	0.00180
	2007	19.953035	176.12475	193.69397	47.15750	7.473490	2.154664	0.69667	0.85570
	2008	0.0008696	0.0004861	0.0003881	0.000306	0.000242	0.000191	0.00015	0.00180
	2009	11.700943	27.253468	69.865100	32.21795	1.834552	0.263003	0.00101	0.00176
	2010	0.0008696	0.0004861	0.0003881	0.000306	0.000242	0.000191	0.00015	0.00180
	2011	95.600268	257.99292	577.24848	103.7147	28.14660	7.253016	2.58496	2.77874

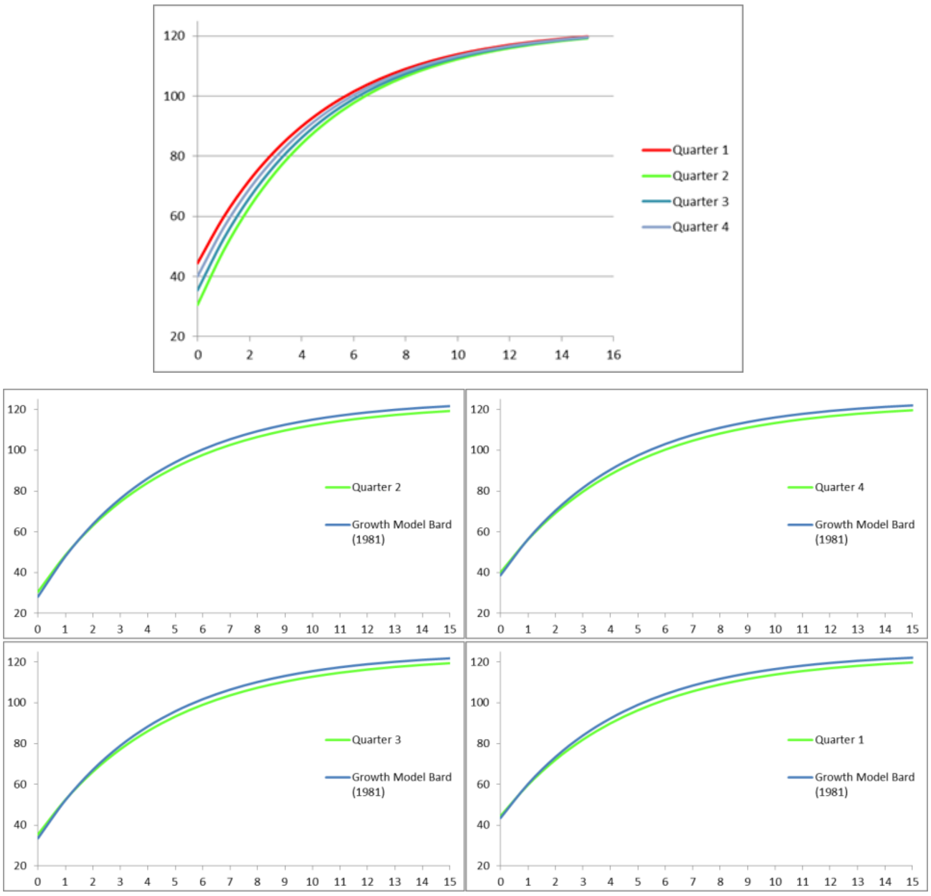

Figure 1. Estimated mean size at age by quarter and age for the north albacore stock.

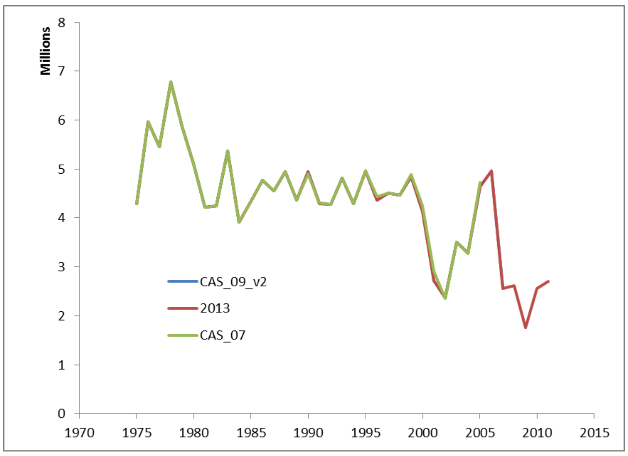

Figure 2. Annual number of the albacore fish in the CAS matrices of 2007, 2009 and 2013 stock assessment evaluations.

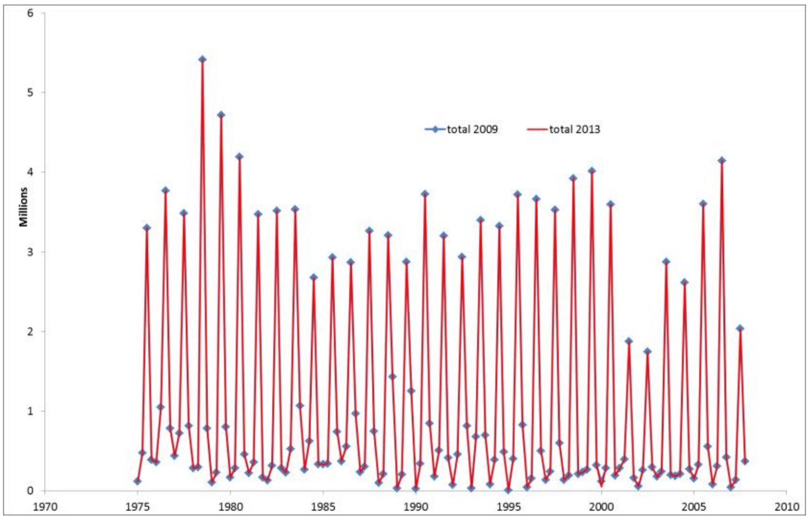

Figure 3. Comparison of the CAS (numbers of fish) by year and quarter between the 2009 and 2013 matrices.

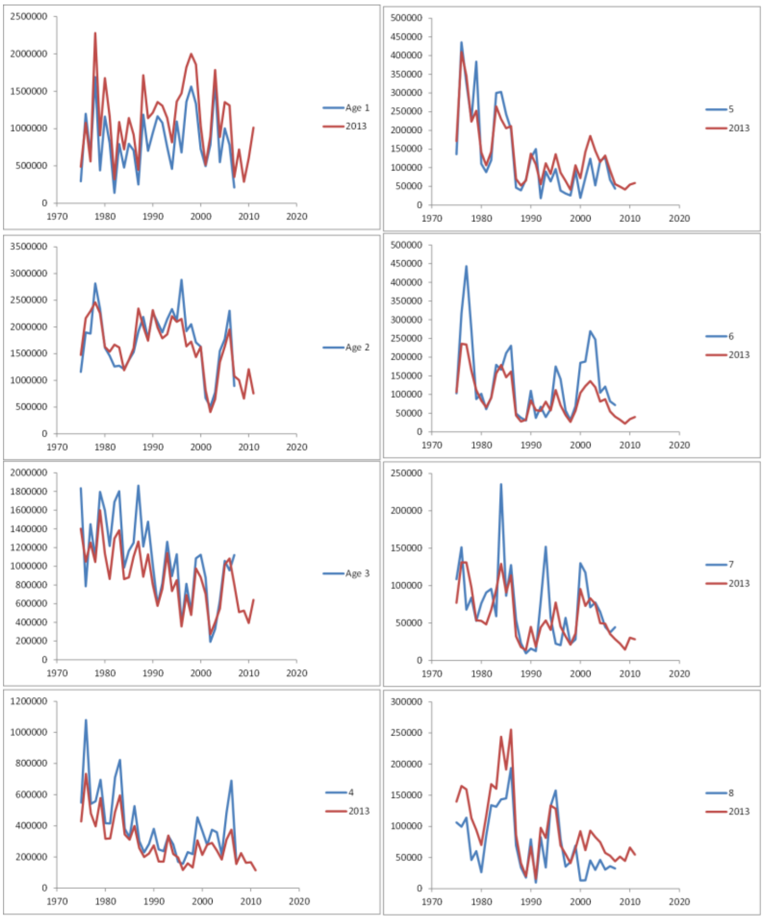

Figure 4. Comparison of the CAA 2013 (red line) and 2009 (blue line) by age class. Age 1 includes ages 0 and 1, age 8 is a plus group.

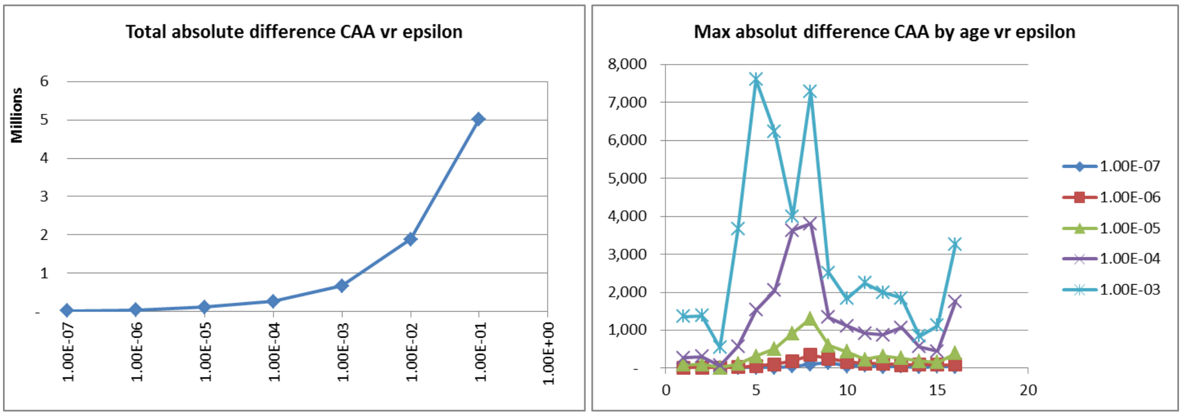

Figure 5. Test results of the Kimura-Chikuni epsilon (0.1 to 1 E-07) setting for ageing a common CAS input matrix. Left panel shows the overall differences in total numbers of fish. Right panel shows the maximum absolute difference by age class for each epsilon scenario.

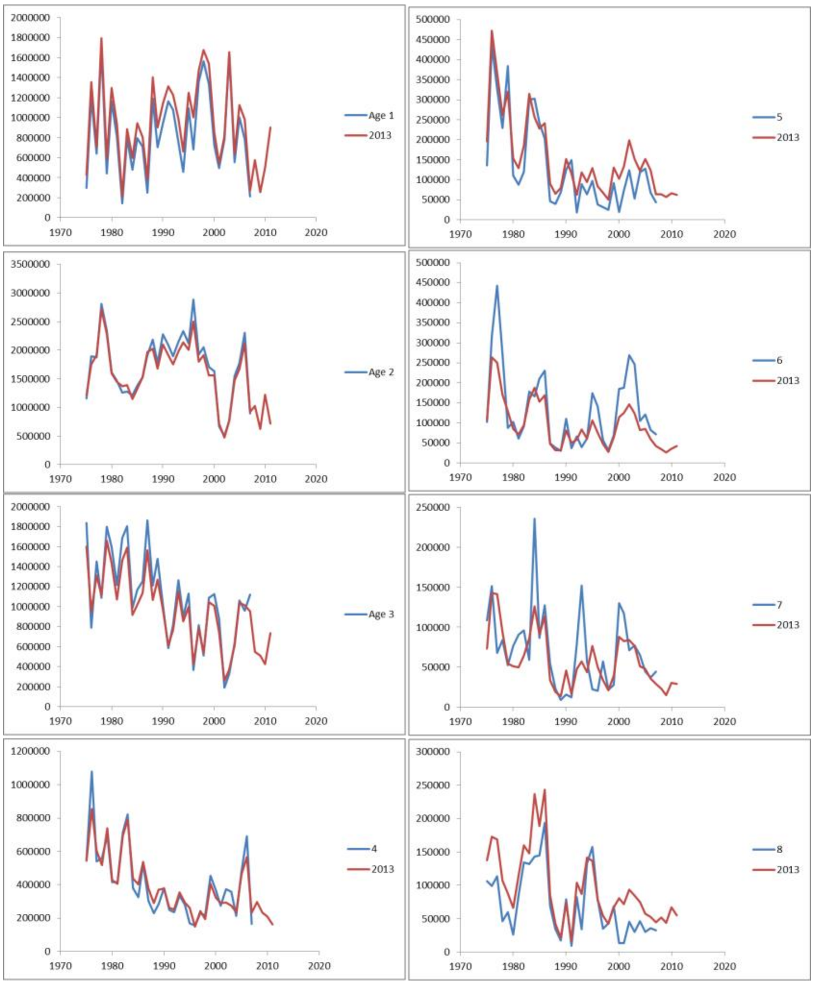

Figure 6. Comparison of the CAA 2013 (red line) and 2009 (blue line) by age class. Age 1 includes ages 0 and 1, age 8 is a plus group.

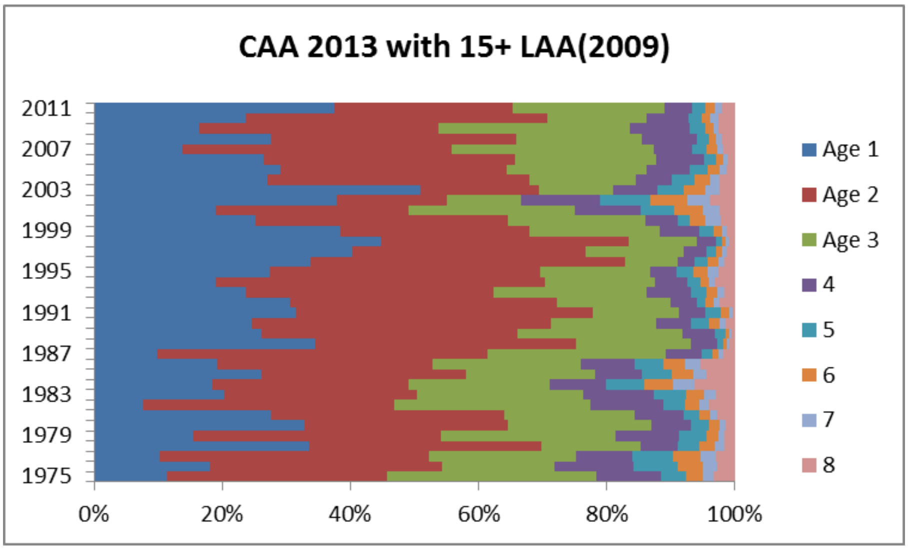

Figure 7. 2013 CAA estimated with KC algorithms, MLAA as shown in Table 1, and using CAS calendar quarter.

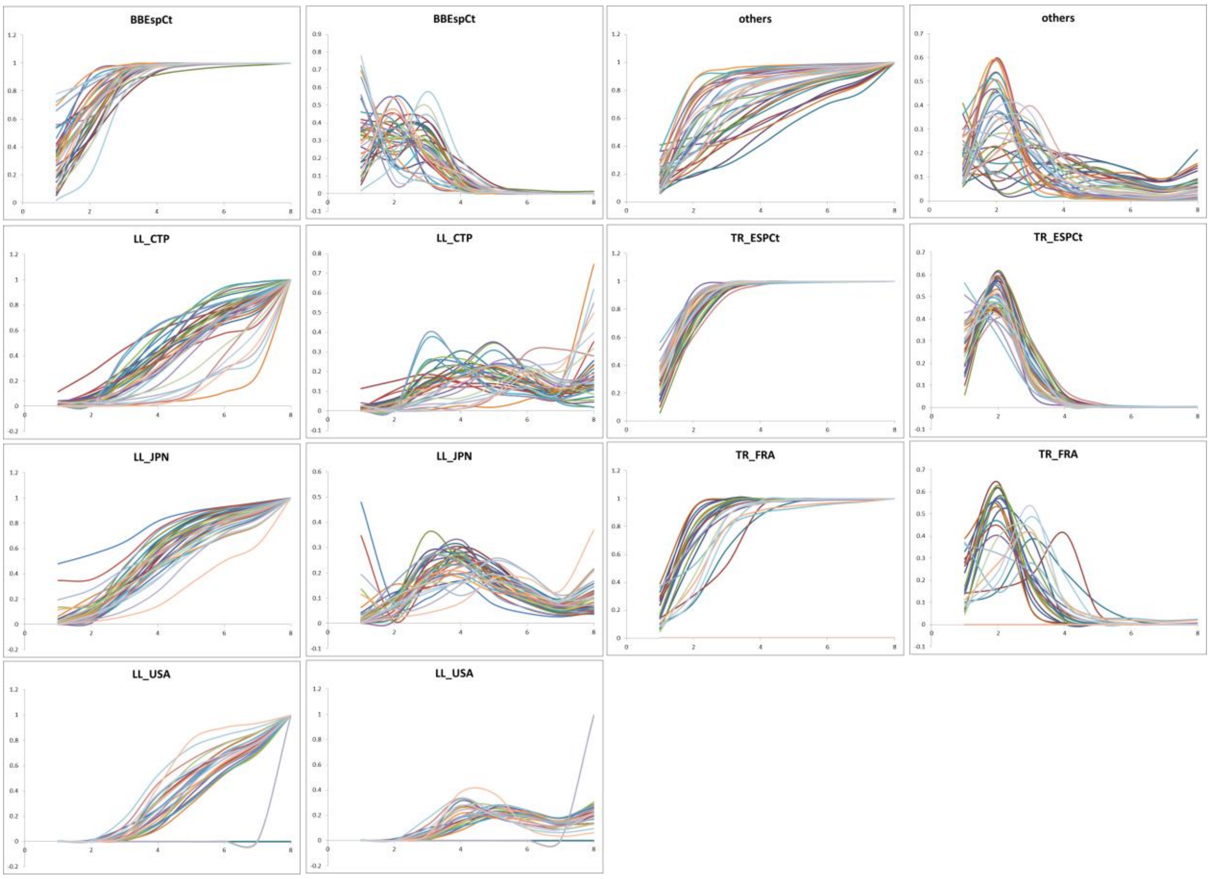

Figure 8. PCAA by N-ALB Fleet VPA input. Cumulative (left) and density distribution (right) annual trends.