Preliminary stock assessments for albacore tuna (*Thunnus alalunga*) in the Indian Ocean using Statistical-Catch-At-Age (SCAA)

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Abstract

We preliminary attempted stock assessments for albacore tuna (*Thunnus alalunga*) in the Indian Ocean using Statistical-Catch-At-Age (SCAA) with 64 years data (1954-2017) including joint CPUE (Japan, Korea and Taiwan) in 4 regions. Very preliminary results show that the stock status (2017) is in the yellow zone of the Kobe plot (SSB/SSBmsy=0.65 and F/Fmsy=0.73). As this is very preliminary with very limited grid search for uncertainties thus the results should not be used for management advices.

Contents

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1. INTRODUCTION

We attempted the stock assessment on albacore (*Thunnus alalunga*) (ALB) in the Indian Ocean by AD Model Builder implemented Statistical-Catch-At-Age (SCAA) (Nishida *et al*) (2015) using available information for 68 years from 1950-2017. It is essential and important to have a few stock assessments from simple model (e.g. ASPIC), inter-medium model (e.g. VPA), inter-mediate integrated models (e.g. SCAA, SCAS, etc.) to full integrated models (e.g. SS3 and MFCL), so that we can compare results under different structure of the dynamic models and evaluate results. If we can get similar results, we have more certainty (confident) in the stock result (status) even there are large uncertainties in the data and models.

2. INPUT INFORMATION

To implement SCAA, we used ALB annual nominal catch by fleet, standardized CPUE (STD_CPUE), CAA (catch-at-age) by fleet and biological information. Below are descriptions of the data used in the SCAA runs.

2.1 Stock structure

In the Pacific and the Atlantic Ocean, two (north and south) stocks hypothesis has been used and stock assessments have been conducted for each stock. As for the Indian Ocean, it has a very small northern part, thus a single stock hypothesis has been applied, although there is some knowledge on intermingled areas with Pacific and Atlantic stocks in its eastern and western end respectively. Nevertheless, we assume a single stock hypothesis for the 2019 stock assessment as in the past.

2.3 Temporal unit

The temporal unit of SCAA is the annual based.

2.2 Sub-areas

Considering the features of ALB fisheries and habitats in the Indian Ocean, four sub-areas has been defined by WPTmT07 (Data prep) (2019) (Fig. 1).

2.3 Gears

WPTmT07 (Data prep) meeting defined four gear types as below:

LL *: Tuna longline fisheries*
DG *: Drift gillnet fisheries (Taiwan)*
PS *: Purse seine fisheries*
OTH *: Other fisheries including small scale surface fisheries such as troll, pole and lines, lines, gillnet (off shore) and other minor fisheries.*

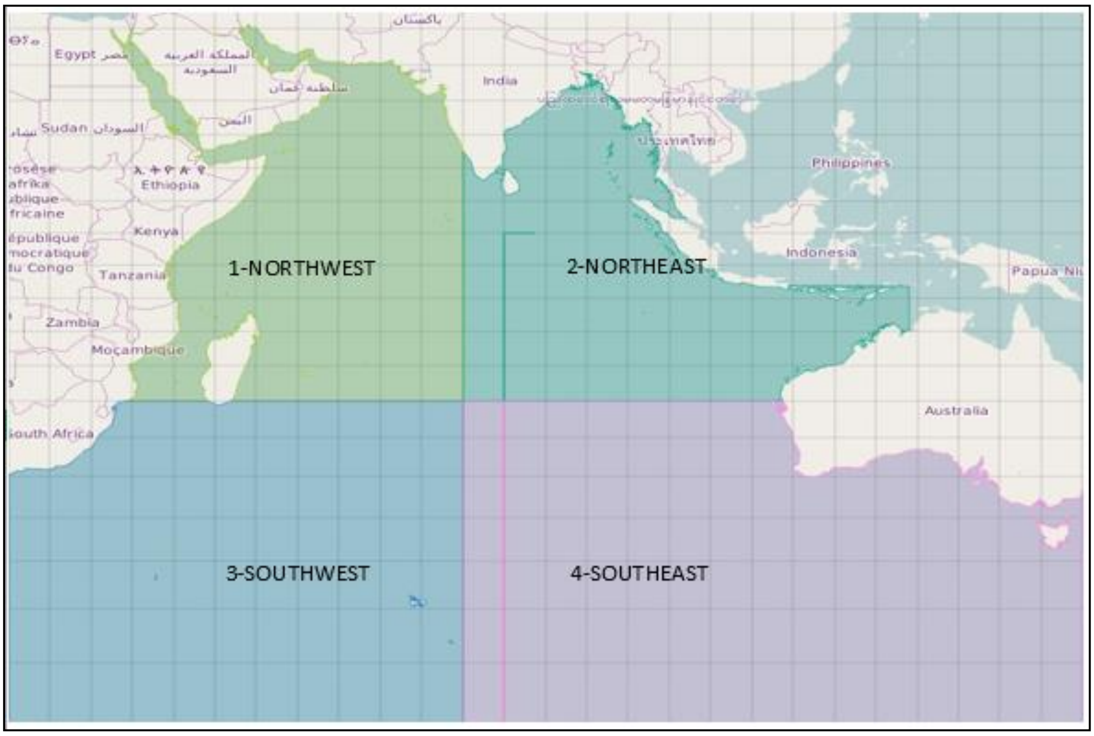


Fig.1 Four sub-areas and corresponding 11 fisheries (IOTC, 2019)

2.4 Catch

Fig. 2 shows catch by gear in the whole Indian Ocean and Fig. 3 by subarea. Major gear to catch ALB is LL for all sub areas and the secondary catch is DN for 1988-1992 in subarea 4. Catch by other gears and other subareas are negligible

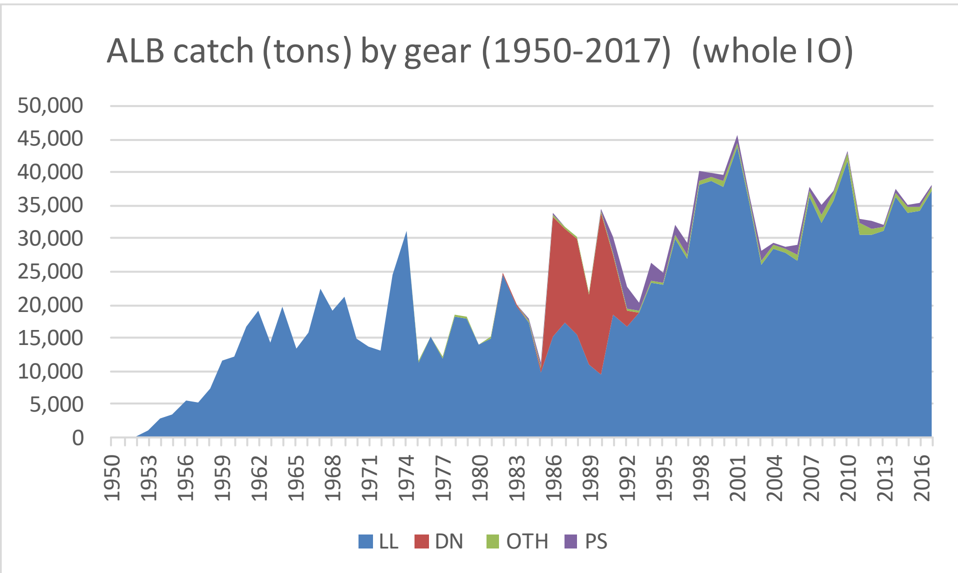


Fig. 2 ALB catch by gear (1950-2017)

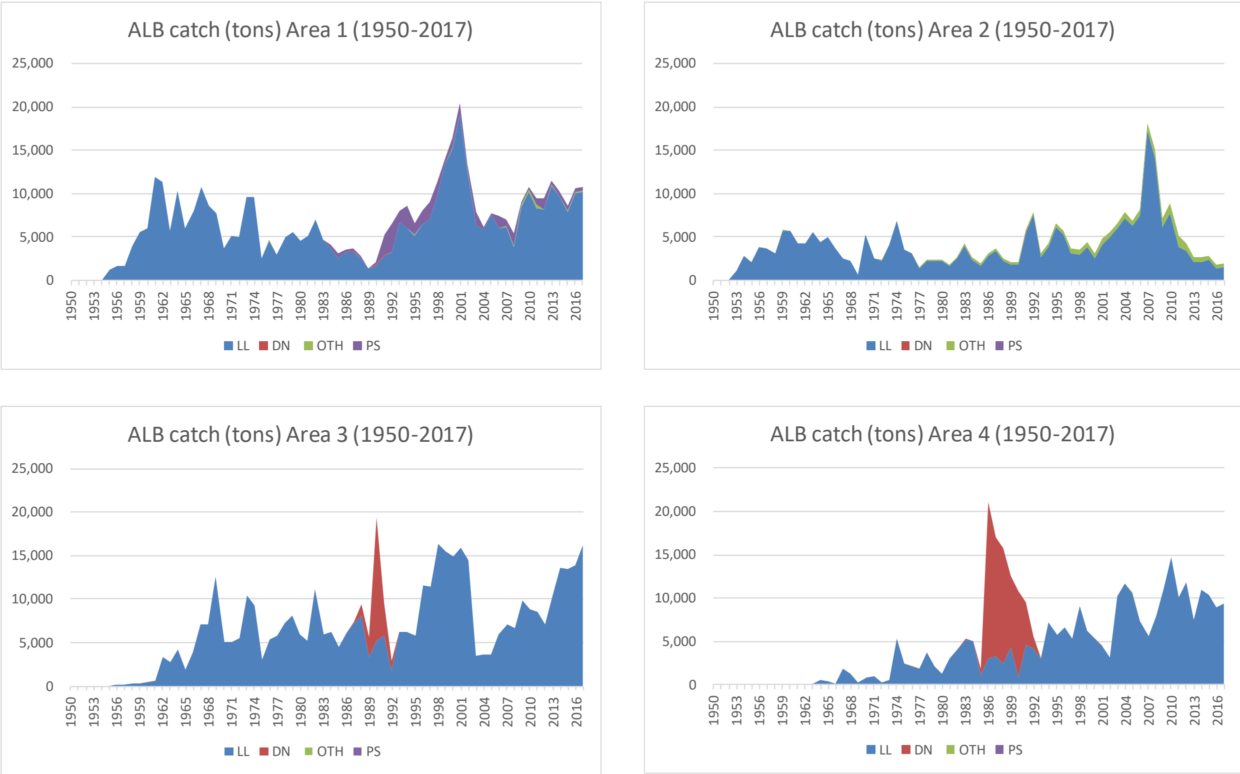


Fig. 3 ALB catch by subarea (1950-2017)

2.5 Fleet for SCAA

WPTmT7(data prep) (Jan 2019) meeting suggested to use 11 types of fleets (fisheries) including LL (tuna longline fisheries), DN (drift gillnet fisheries by Taiwan), PS (purse seine fisheries) and OTH (other fisheries) in four subareas (Table 1). Using CAA estimated by the IOTC Secretariat (IOTC, 2019), we investigate the situation of the data. Table 2 shows catch (1,000 number of fish) by fleet. There are very few data during 1950-1953, thus we use the data for 64 years from 1954-2017 for the robust stock assessments. In addition, there almost nil data for OTH3 and OTH4, thus we pool the data OTH1+OTH3 as OTH13 and OTH2+OTH4 as OTH34 also for the robust stock assessments.

Table 1 Eleven types of area specific fisheries defined by WPTmT7 (data prep) meeting (Jan 2019).

No	Fishery	Nationality	Gear	Area
1	LL1	All	Longline	1
2	LL2	All	Longline	2
3	LL3	All	Longline	3
4	LL4	All	Longline	4
5	DN3	CN-TW	Drift net	3
6	DN4	CN-TW	Drift net	4
7	PS1	All	Purse seine	1
8	OTH1	All	Others	1
9	OTH2	All	Others	2
10	OTH3	All	Others	3
11	OTH4	All	Others	4

Table 2 Catch (1,000 number of fish) by fleet

	LL1	LL2	LL3	LL4	DN3	DN4	PS1	OT1	OT2	OT3	OT4	Total
1950	0	0	0	0	0	0	0	1	1	0	0	2
1951	0	0	0	0	0	0	0	1	5	0	0	6
1952	0	3	0	0	0	0	0	1	5	0	0	9
1953	0	50	0	0	0	0	0	1	5	0	0	56
1954	4	123	0	0	0	0	0	1	7	0	0	134
1955	57	95	4	0	0	0	0	1	7	0	0	163
1956	80	177	6	0	0	0	0	1	7	0	0	271
1957	75	169	7	0	0	0	0	1	7	0	0	259
1958	184	150	17	0	0	0	0	1	7	0	0	359
1959	252	288	22	0	0	0	0	1	7	0	0	570
1960	263	279	34	2	0	0	0	1	7	0	0	586
1961	574	209	35	0	0	0	0	1	6	0	0	826
1962	524	204	242	2	0	0	0	1	8	0	0	980
1963	275	276	197	7	0	0	0	1	8	0	0	763
1964	518	217	201	28	0	0	0	1	8	0	0	974
1965	291	246	126	22	0	0	0	1	9	0	0	694
1966	393	185	273	4	0	0	0	1	10	0	0	866
1967	580	129	544	119	0	0	0	2	10	0	0	1,383
1968	483	110	410	85	0	0	0	3	10	0	0	1,102
1969	405	34	936	21	0	0	0	3	11	0	0	1,411
1970	198	306	310	40	0	0	0	4	9	0	0	868
1971	288	151	354	59	0	0	0	5	9	0	0	867
1972	269	140	290	16	0	0	0	5	11	0	0	731
1973	513	247	816	30	0	0	0	4	11	0	0	1,621
1974	539	417	680	326	0	0	0	5	12	0	0	1,980
1975	129	203	165	150	0	0	0	4	18	0	0	668
1976	251	176	309	126	0	0	0	4	20	0	0	886
1977	164	79	357	110	0	0	0	3	23	0	0	737
1978	229	121	445	235	0	0	0	5	50	0	0	1,084
1979	244	116	502	128	0	0	0	4	47	0	0	1,040
1980	194	116	377	74	0	0	0	3	53	0	1	819
1981	205	87	334	183	0	0	0	3	59	0	0	871
1982	312	137	689	246	0	12	1	3	78	0	0	1,478
1983	194	199	366	324	0	13	0	2	77	0	0	1,176
1984	160	109	401	299	0	0	19	2	51	0	0	1,042
1985	110	76	282	84	0	71	24	0	21	0	0	668
1986	140	139	353	191	0	1,680	9	0	50	0	0	2,563
1987	124	144	438	212	24	1,277	9	0	98	0	0	2,327
1988	101	97	507	165	131	1,414	9	1	143	0	0	2,568
1989	49	81	207	274	241	861	0	1	124	0	0	1,837
1990	68	78	316	57	1,684	1,035	12	1	94	4	0	3,349
1991	111	287	369	297	434	511	78	1	127	0	4	2,219
1992	174	399	136	264	123	148	120	3	116	0	0	1,482
1993	282	118	382	199	0	0	47	5	172	1	0	1,206
1994	231	156	368	469	0	0	93	13	189	0	0	1,519
1995	201	268	393	365	0	0	49	14	193	0	0	1,483
1996	268	236	695	422	0	0	57	14	222	0	0	1,915
1997	277	133	725	325	0	0	82	18	232	0	0	1,793
1998	417	138	1,043	584	0	0	59	12	249	0	1	2,503
1999	525	183	979	389	0	0	23	4	259	0	2	2,364
2000	676	108	927	325	0	0	50	17	295	0	0	2,400
2001	1,155	205	1,032	289	0	0	55	20	281	1	1	3,038
2002	778	291	937	199	0	0	27	15	240	0	5	2,491
2003	371	283	194	540	0	0	60	14	251	0	2	1,714
2004	300	324	243	596	0	0	9	17	290	0	2	1,780
2005	387	301	245	578	0	0	6	16	237	0	3	1,774
2006	267	326	395	372	0	0	60	11	284	0	0	1,715
2007	281	776	430	260	0	0	27	51	329	0	0	2,154
2008	182	605	418	463	0	0	56	53	427	1	0	2,203
2009	376	235	517	640	0	0	15	61	421	1	0	2,265
2010	454	357	592	995	0	0	9	62	463	1	0	2,933
2011	416	163	569	551	0	0	29	54	540	5	1	2,327
2012	374	165	533	721	0	0	53	41	382	2	0	2,271
2013	450	105	717	539	0	0	20	34	250	0	0	2,116
2014	466	100	987	760	0	0	25	20	222	0	0	2,580
2015	362	106	820	649	0	0	23	62	218	0	0	2,241
2016	435	94	900	653	0	0	18	38	128	1	0	2,266
2017	390	84	932	622	0	0	17	62	139	0	0	2,246

Thus, we will use the data from 1954-2017 for 9 fleets (LL1-LL4, DG3-DG4, PS1, OTH13 and OTH24) (Table 3 and Fig 4). In addition the current SCAA can handle three CPUE (max), so we pool CPUE area as LL34.

Table 3 Eight types of area specific fisheries revised from 11 types defined by WPTmT7 (data prep) meeting (Jan 2019).

No	Fishery	Nationality	Gear	Area
1	LL1	All	Longline	1
2	LL2	All	Longline	2
3	LL34	All	Longline	3+4
4	DN3	CN-TW	Drift net	3
5	DN4	CN-TW	Drift net	4
6	PS1	All	Purse seine	1
7	OTH13	All	Others	1+3
8	OTH24	All	Others	2+4

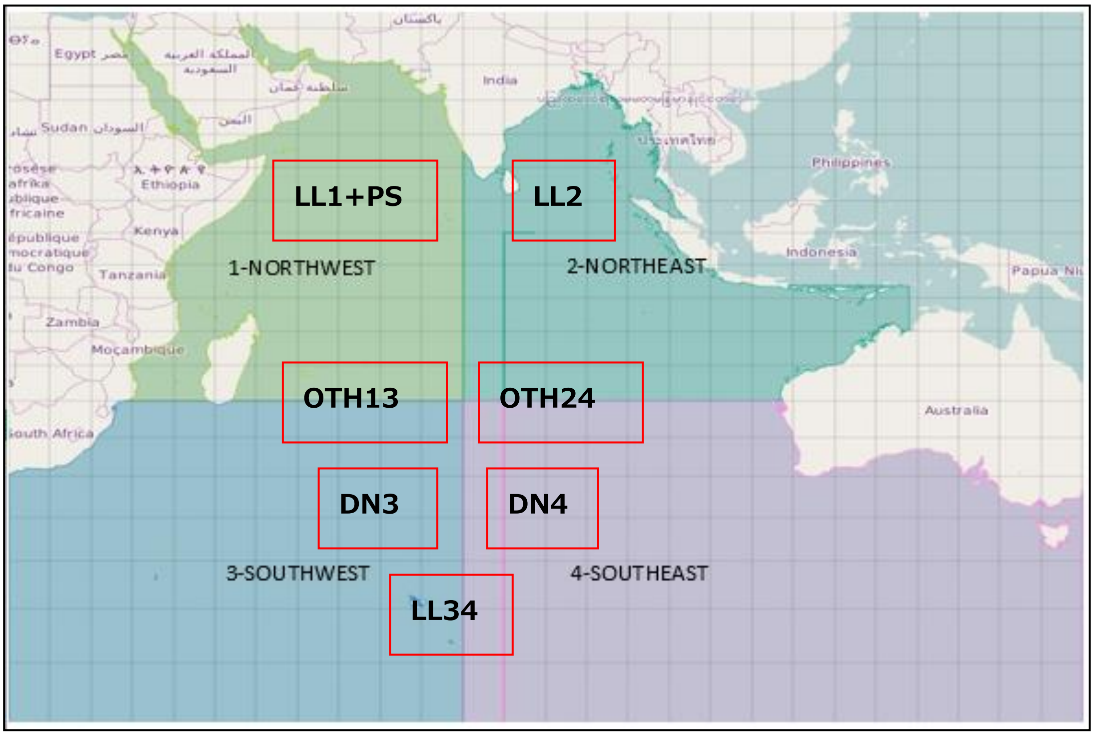


Fig. 4 Eight fleets to be used for SCAA

2.6 Plus and minus group and seeding values of selectivity

In running SCAA, plus and minus groups need to be set up to implement robust optimization. Based on the CAA information by fleet, we determined plus and minus groups which CAA by age composition less than 2% of the total CAA (personal communication with Dr Butterworth). We also set up the seeding values of selectivity and the anchored values (age with the highest selectivity=1) (Table 4).

Table 4 Minus and plus group, age specific seeding values for selectivity and the anchored age with the highest selectivity (=1).

	Code	Minus group (Age)	Plus group (Age)	Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1)	LL1	1-	13+	1954-2017		0.02	0.4	0.85	(1)	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99		
(2)	LL2	2-	13+	1954-2017			0.39	0.82	0.99	(1)	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99		
(3)	LL34	1-	11+	1955-2017		0.34	0.86	(1)	0.72	0.47	0.34	0.2	0.19	0.18	0.17	0.16				
(4)	DN3	0	6+	1987-1992	0	(1)	0.51	0.03	0	0	0									
(5)	DN4	0	6+	1982-1992	0	(1)	0.71	0.03	0	0	0									
(6)	PS1	4-	15+	1982-2017					0.49	0.76	(1)	0.92	0.84	0.71	0.51	0.42	0.42	0.42	0.42	0.31
(7)	OTH13	0	6+	1954-2017	0	(1)	0.60	0.16	0	0	0									
(8)	OTH24	0	4+	1954-2017	0	(1)	0.45	0.03	0											

2.7 standardized CPUE

(1) LL

WPTmT07 (Data prep) meeting (January 2019) suggested to use the joint LL CPUE (Holye et al 2019). As SCAA is based on year (season aggerated) and area, we use annual and area based standardized joint CPUE. In each area, there are four types of standardized CPUE as shown in Table 5.

Table 5 Four types of joint standardized CPUE (Holye et al 2019)

Type	Attributes	Period	Years
[A]	With vessel ID (later period)	All	1955-2017
[B]	No Vessel ID	Earlier	1956-1979
[C]	No Vessel ID	All	1955-2017
[D]	With vessel ID	Later	1979-2017

To evaluate plausible type of standardized CPUE by area, we investigated negative correlations between catch (age 2 or older, major age classes exploited by longline) and standardized CPUE. Fig 5 shows results implying that the most plausible standardized CPUE for area 1 (NW) is type [A] (37%), area 2 (NE) type[B] (54%) and area 3+4 (SW+SW) type [A] (30%). Fig 6 shows catch and standardized CPUE by area and joint CPUE type. Standardized CPUE with vessel ID and earlier periods are more plausible because vessel ID can reduce biases in q (catchability) caused by skipper's abilities, while inclusions of catch and standardized CPUE in earlier period can explain well their plausible relations (negative correlations).

Catchability by gear and boat evolution is not considered (such as 1% increased by year) is not considered for the base case. If time is allowed, we will attempt 1% scenario.

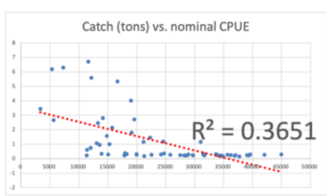
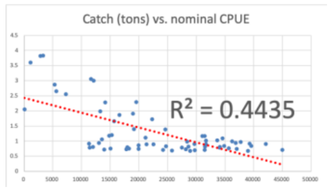
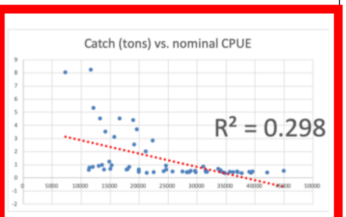
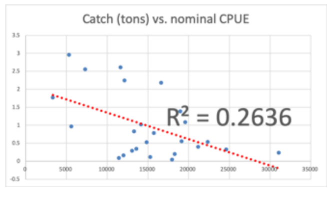
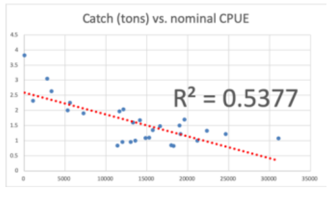
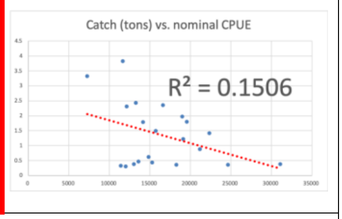
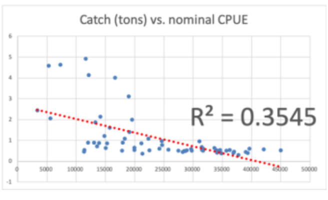
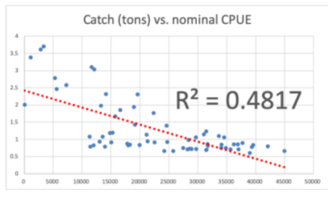
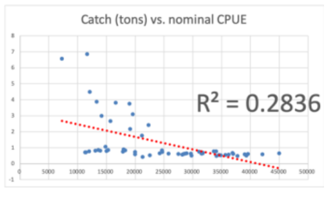
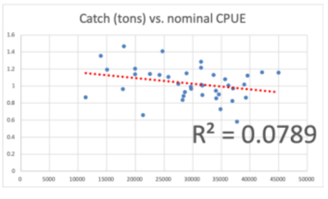
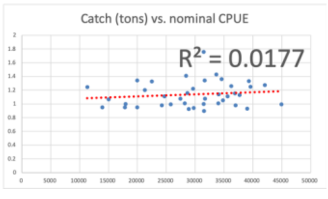
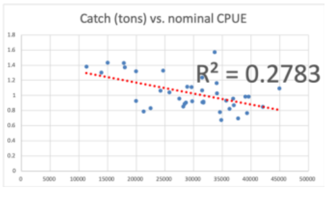
CPUE	1 NW	2 NE	3+4 SW+SE
[A] **5517_V**			
[B] **5579_NV**			
[C] **5517_NV**			
[D] **7917_V**			

Fig 5 Relation between catch and standardized CPUE by area and joint CPUE type

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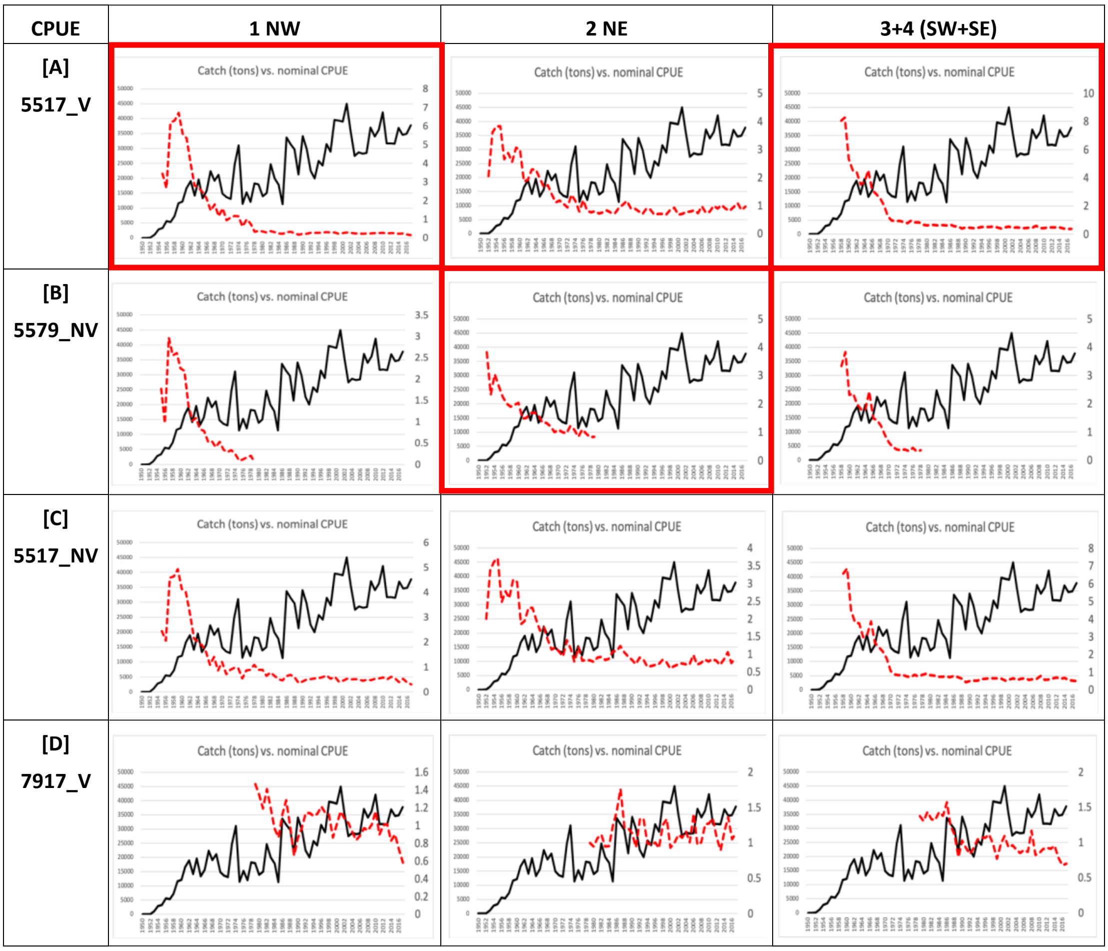

Fig 6 Catch and standardized CPUE by area and joint CPUE type

(STD CPUE in red square will be used for SCAA)

(2) Other CPUE

Other CPUE such as PS, GILL and OTH maybe available in the IOTC database are not considered for the base case. If time is allowed, we will attempt to use.

2.8 Biological information

We use agreed biological parameters in the WPTmT07 (data prep) (January 2019) for SCAA. We will conduct SCAA for the base case.

(1) Stock structure

Single stock is assumed.

(2) Sex ratio at birth

1:1 also for the rest of the life.

(3) Weight-at-age (beginning and mid-year)

Using the LW relation by Penny (1994) (South Atlantic) (Fig. 7) and growth equation by Farley et al (2019) based on Von Bertalanffy (Fig. 8), we computed Weight-at-age (beginning and mid-year) (Table 6). Table 7 shows those use for SCAA. Please note that we use sex combined (average) growth equation.

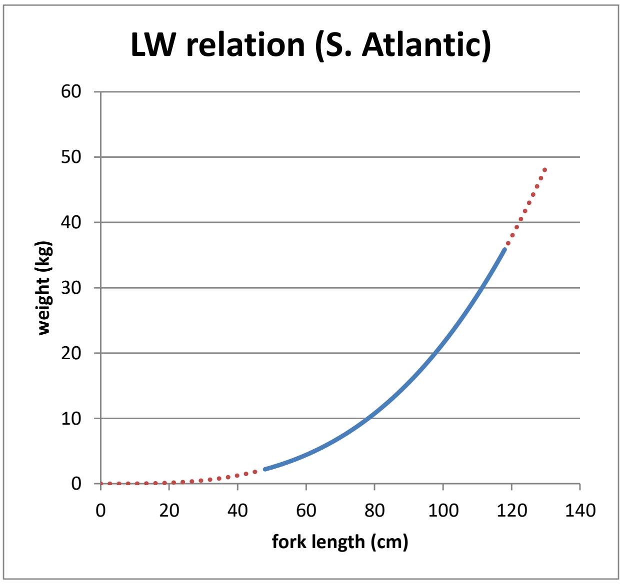

Fig. 7 LW relation by Penny (1994): W = (1.3718 × 10-5) *L3.0973

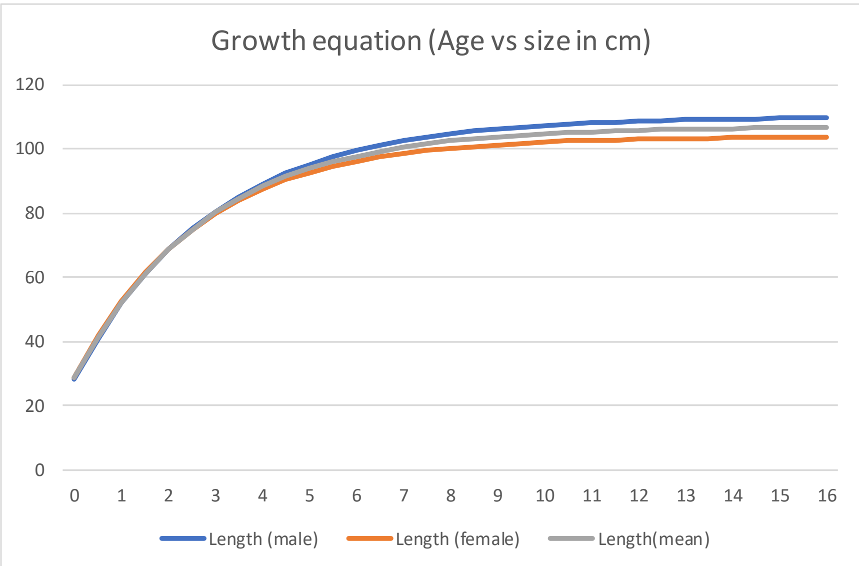

Fig 8 Growth equation by sex (Farley et al, 2019)

♂ L(t)=110.06 [1-e-0.34 (t+0.87)]

♀ L(t)=103.80 [1-e-0.38 (t+0.86)]

Table 6 Computed Age-Length-Weight keys

Age	Length(cm)	Weight (kg)
0	28.6	0.4
0.5	41.4	1.4
1	52.2	2.9
1.5	61.2	4.7
2	68.7	6.7
2.5	75.0	8.8
3	80.2	10.8
3.5	84.6	12.8
4	88.2	14.6
4.5	91.3	16.2
5	93.9	17.6
5.5	96.0	18.9
6	97.8	20.0
6.5	99.3	21.0
7	100.5	21.8
7.5	101.6	22.5
8	102.4	23.1
8.5	103.2	23.7
9	103.8	24.1
9.5	104.3	24.5
10	104.7	24.8
10.5	105.1	25.0
11	105.4	25.3
11.5	105.6	25.4
12	105.8	25.6
12.5	106.0	25.7
13	106.2	25.8
13.5	106.3	25.9
14	106.4	26.0
14.5	106.5	26.1
15	106.6	26.1

Table 7 Weight-At-Age (beginning and middle of year) (tons) for SCAA inputs

Age (beginning)	0	1	2	3	4	5	6	7
Weight (tons)	0.00044	0.00287	0.00671	0.01084	0.01457	0.01764	0.02003	0.02182
Age (middle)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5
Weight (tons)	0.00140	0.00469	0.00879	0.01278	0.01620	0.01892	0.02099	0.02253

8	9	10	11	12	13	14	15
0.02314	0.02409	0.02477	0.02526	0.02560	0.02585	0.02602	0.02614
8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.02365	0.02446	0.02504	0.02545	0.02574	0.02594	0.02608	0.02619

(4) M (natural mortality)

We use M=0.3 by Watanabe et al (2006) (North Pacific) as a base case.

(5) Maturity-at-age

WPTmT07 (data prep) (January 2019) suggested to use Farley et al (2014) (South Pacific) Maturity-at-age will be converted by the growth equation by Farley et al (2019). To implement this, we get the maturity at length data from Farley. Then we converted to age using the growth equation for female, i.e., L(t)=103.80 [1-e-0.38 (t+0.86)] (Farley et al, 2019). Fig. 9 and Table 9 show results.

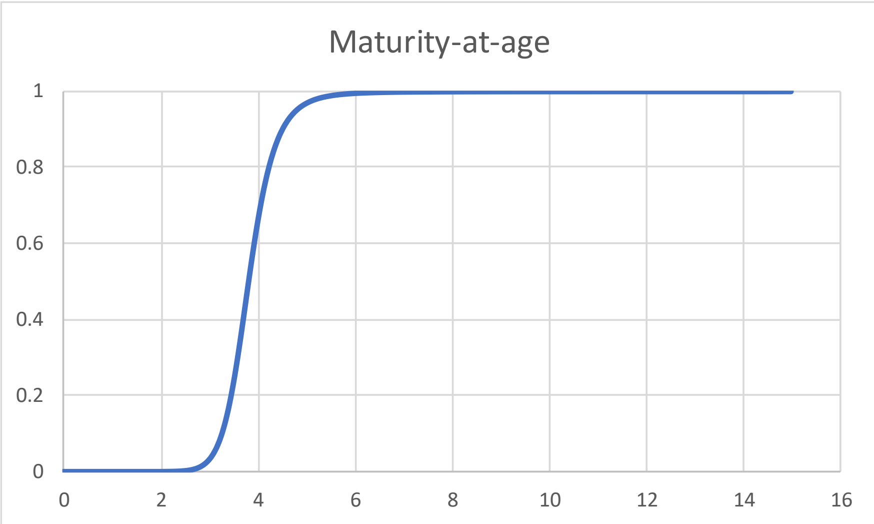

Fig. 9 Maturity-at-age

based on Maturity-at-size (Farley et al 2014) and the growth equation (Farley et al 2019)

Table 8 Maturity-at-age based on Maturity-at-size (Farley et al 2014) and the growth equation (Farley et al 2019)

Age	0	1	2	3	4	5	6	7	8	9	10	11	12+
Maturity –at-age	0	0	0	0.029	0.629	0.970	0.995	0.999	1	1	1	1	1

(6) Fecundity

We assume that fecundity is proportional to female weight at age.

3. SCAA

3.1 Grid search

We attempted SCAA runs using input data described in the previous Section. To search optimum parameters, we conducted the grid search using 27 scenarios (Table 9).

Table 9 Specification (Scenario) of grid search

Parameters	Search range and interval	No of scenarios
h (steepness)	0.7, 0.8 and 0.9	3
Sigma R (SR fluctuation)	0.6, 0.7, 0.8 and 0.9	4
(*) Weighting for CAA = [Multiple] x [C] [C] = Coverage (sample number of size) = (number of size measured) / (total catch in number)	1.0[C], 0.1 [C]	2
Total		24

(*) Weighting for CAA by fleet

In SCAA, weightings for CAA by fleet need to assign. The normal (default) weightings for CAA are [C]: coverages of size sample, i.e., (number of size measured)/ (total catch in number) by fleet. We investigated [C] by fleet and Table 7 shows results. As we are interested in different weighting schemes to investigate optimum parameters, we set 2 scenarios using different multiples, i.e., 1.0 [C] and 0.1[C] (Table 10).

Table 10 Six weighting schemes for CAA using [C]

[C]: coverages of size sample = (number of size measured)/ (total catch in number)

	1.0 [C]	0.1 [C]
LL1	0.00264371	0.00026437
LL2	0.02767646	0.00276765
LL34	0.00780520	0.00078052
DN3	0.00028696	0.00002870
DN4	0.00153919	0.00015392
PS1	0.18538508	0.01853851
OT13	0.00001919	0.00000192
OT24	0.00057421	0.00005742

4.2 Results (Table 11)

Table 11 shows results. 9 runs are resulted as plausible and 15 as NC or NP.

Table 11 Results of SCAA runs (24 scenarios)

No.	0.1 [C] or 1.0 [C]	Steepness	Sigma	h	SSB0	likelihood(total)	R2	SSB/SSBmsy	F/Fmsy	RESULTS
1	0.1 [C]	0.7	0.6	0.7	447	-223	0.97	0.51	1.95	NP
2	0.1 [C]	0.7	0.7	0.7	656	-209	0.98	0.36	3.32	NP
3	0.1 [C]	0.7	0.8	0.7	474	-199	0.88	0.46	1.33	NP
4	0.1 [C]	0.7	0.9	0.7	460	-226	0.97	0.50	2.22	NP
5	0.1 [C]	0.7	0.6	0.8	NC					NC
6	0.1 [C]	0.8	0.7	0.8	448	-201	0.98	0.37	1.74	NP
7	0.1 [C]	0.8	0.8	0.8	501	-218	0.98	0.56	2.63	NP
8	0.1 [C]	0.8	0.9	0.8						NC
9	0.1 [C]	0.9	0.6	0.9	339	-138	0.87	0.34	1.00	NP
10	0.1 [C]	0.9	0.6	0.9	NC					NC
11	0.1 [C]	0.9	0.8	0.9	481	-209	0.98	0.47	1.62	NP
12	0.1 [C]	0.9	0.9	0.9	402	-213	0.98	0.27	0.65	NP
13	1.0 [C]	0.7	0.6	0.7	615	-46	0.97	0.75	2.56	NP
14	1.0 [C]	0.7	0.7	0.7	1335	-59	0.94	0.33	1.31	P
15	1.0 [C]	0.7	0.8	0.7	1339	-58	0.98	0.63	0.77	P
16	1.0 [C]	0.7	0.9	0.7	1888	-74	0.94	0.24	1.28	P
17	1.0 [C]	0.8	0.6	0.8						NC
18	1.0 [C]	0.8	0.7	0.8						NC
19	1.0 [C]	0.8	0.8	0.8	1146	-57	0.98	0.76	0.67	P
20	1.0 [C]	0.8	0.9	0.8	1348	-61	0.98	0.74	0.62	P
21	1.0 [C]	0.9	0.6	0.9						NC
22	1.0 [C]	0.9	0.7	0.9	882	-52	0.97	1.00	0.57	NC
23	1.0 [C]	0.9	0.8	0.9	1123	-57	0.97	0.65	0.73	P
24	1.0 [C]	0.9	0.9	0.9	1193	-60	0.98	1.01	0.50	P

Note: In 1,000 tons, NC: Not converged NP: not plausible, P: Plausible

Fig. 10 shows location of 7 plausible SCAA runs in the Kobe plot. We decided run # 23 (median point) as the representative point. Table 12 is the summary of the result.

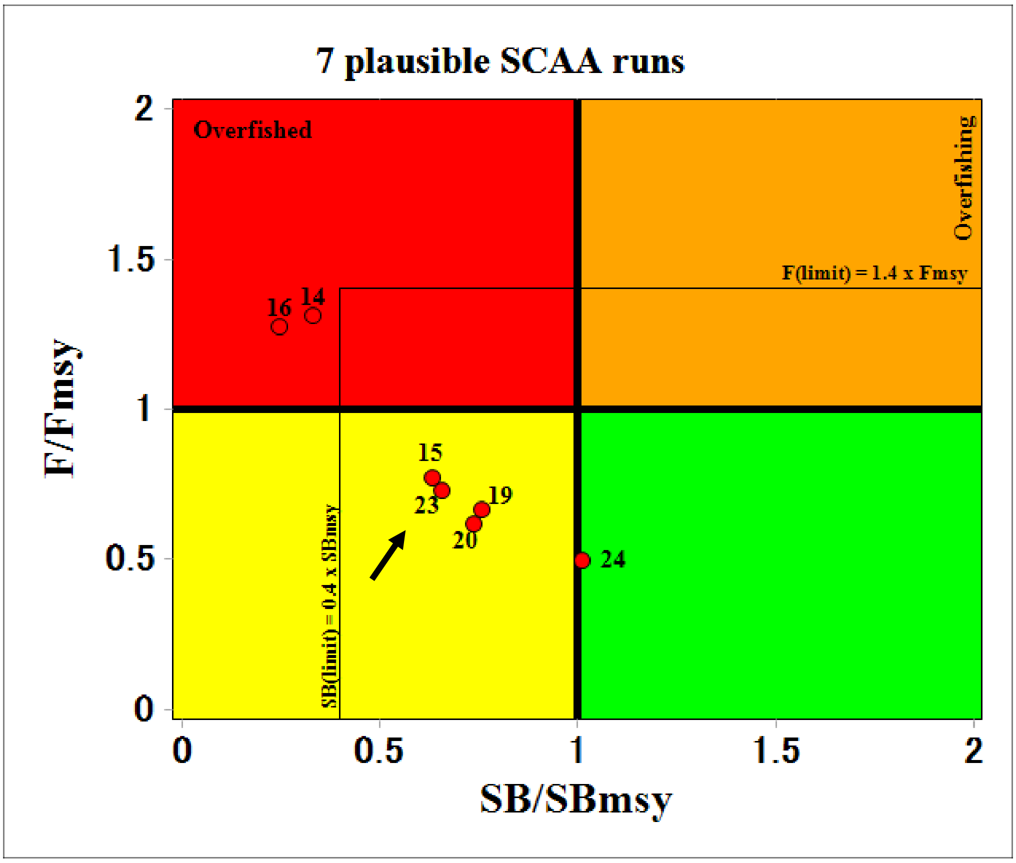

Fig 10 Locations (stock statuses) of 7 plausible SCAA runs (out of 24) in the Kobe plot.

Table 12 Indian Ocean albacore stock status summary based on the SCAA (Run23).

Management Quantity	Indian Ocean
Most recent catch estimate (t) (2017)	38,713
Mean catch over last 5 years (t) (2013-2017)	36,235
MSY (1000 t) (80%CI)	57,196 (NA)
Current data period	1950-2017
F(Current)/F(MSY) (2017) (80% CI)	0.73 (NA)
SB(Current)/SB(MSY) (2017) (80% CI)	0.65 (NA)
SB(Current)/SB(MSY)	NA
B(Current)/B(0) (2017) (80% CI)	0.16 (NA)
SB(Current)/SB(0)	NA
SB(Current)/SB(Current, F=0)	NA

4. Discussion and conclusion

We preliminary attempted stock assessments for albacore tuna (*Thunnus alalunga*) in the Indian Ocean using Statistical-Catch-At-Age (SCAA) with 68 years data (1950-2017) including joint CPUE (Japan, Korea and Taiwan) in 4 regions. Very preliminary results show that the stock status (2017) is in the yellow zone of the Kobe plot (SSB/SSBmsy=0.65 and F/Fmsy=0.73). As this is very preliminary with very limited grid search thus the results should not be use for management advices.

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