Progress in development of Statistical-Catch-At-Size (SCAS) modelling software

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1. Introduction

We are developing Statistical-Catch-At-Size (SCAS) base on ADMB to extend the previous ASPM (later SCAA), which have been used since 2001 inclduing other IOTC species such as yellowfin tuna, albacre tuna and swordfish.

ASPM/SCAA has two major limitations, i.e., (a) selectivities are estimated by model free (ad hoc) approches and (b) CAA is estimated by the slicing methods. These two produce biases in different leveles. To solve thses problems we developed SCAS by modifying ASPM/SCAA softwear including the model based slectivity estimation scheme and to use CAS to avoid biases caused by slicing meghod to estimnate CAA. Although we made such modidifications, the basic designs of SCAS is remained same as ASPM/SCAA software.

The SCAS is now similar to SS3 except two points, i.e., (a) annual basis (season aggretaed) (SS3 normaly quarter basis) and (b) no spatial structrure avaialble as in SS3. We have not yet comleted the future projections and risk assessments parts, thus for this time we did only stock assessments without Kobe II. In the futrue we will complete all parts. The reason why we use SCAS is that SC has been recommending to use diffetent types (strutured) of stock assessment models (e.g. integtaed models such as SS3, prodcution model such as ASPIC and many other types) to compare and confrim results.

We are using BET in the Indian Ocean under a single stock assumption.

2. Fleet types, sub-areas and fisheries

In implementing SCAS we need to define fleet types, sub-areas and fisheries, which is explained as follows. In IOTC BET stock assessment data files (IOTC. 2019), 7 fleet types and 3 sub-areas are defined (Table 1 and BOX 1). Considering sub-areas and fleets, we define 12 fisheries for stock assessments (BOX 1). Table 2 shows periods (years) operated during 1950-2018 for 12 fisheries. LL, BB and OTHRE were operated for almost full periods since 1950's, while others (LLFL, PSLS and PSFS) from 1970's.

Table 1 Seven types of fleets defined in the BET stock assessment (after IOTC, 2019)

IOTC code	Description	Depth
LL	Longline (frozen)	Mid water
FL	Longline (fresh)	Sub-surface
PSLS	Purse seine (log school)	Surface to sub surface
PSFS	Purse seine (free school)	Surface to sub surface
BB	Pole and Line (Bait Boat)	Surface
LINE	Gillnet, handline, troll and costal LL	Surface to sub surface
OTHER	Gillnet, troll line and other minor artisanal gears	Surface to sub surface

BOX 1 Twelve type of fisheries defined by three sub-areas (A1, A2 and A3) (Map below) and seven types of fleets (Table 1) for BET stock assessment (IOTC, 2019) with codes.

3 sub-areas		7 types of fleets						
IOTC area	location	1	2	3	4	5	6	7
		LL	FL	PSLS	PSFS	BB	LINE	OTHER
		12 types of fisheries						
A1	WEST	(1) LL1		(5) PSLS1	(7) PSFS1	(9) BB1		(11) OTHER1
A2	EAST	(2) LL2	(4) FL2	(6) PSLS2	(8) PSFS2		(10) LINE2	(12) OTHER2
A3	SOUTH (West + Central + East)	(3) LL3						

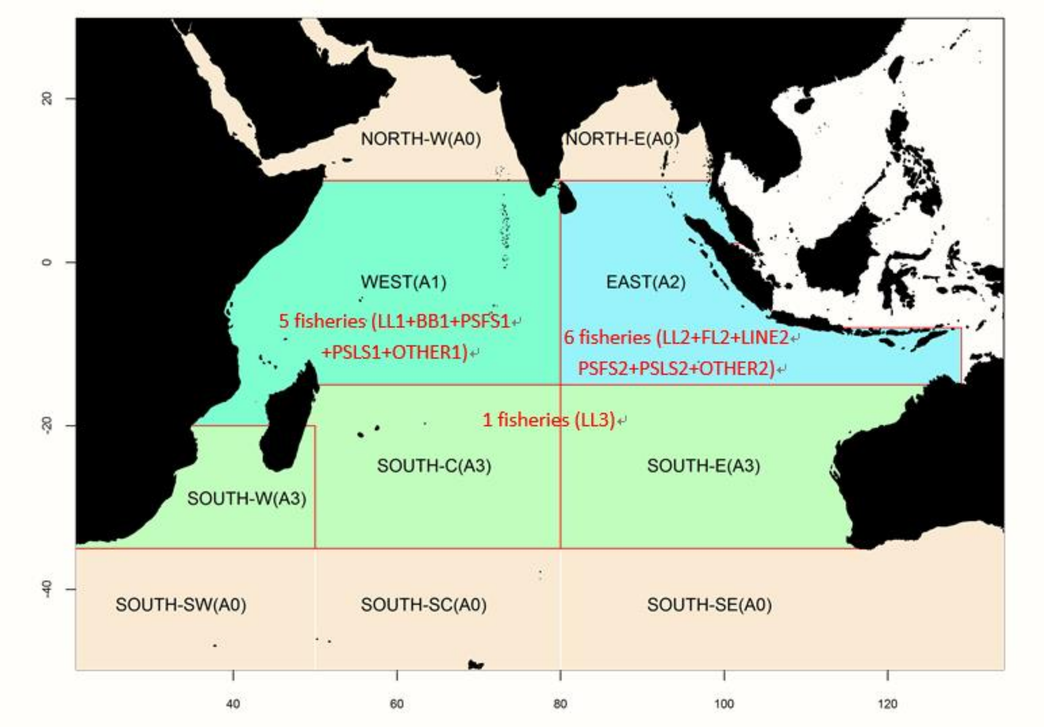

Table 2 Twelve fisheries and years operated

fishereis (no)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Code	LL1	LL2	LL3	FL2	PSLS1	PSLS2	PSFS1	PSFS2	BB	LINE2	OTHER1	OTHER2
stat. yr.	1954	1952	1952	1973	1980	1978	1980	1978	1957	1950	1950	1950
No of yrs	65	67	67	46	39	41	39	41	62	69	69	69
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3. INPUT files

To implement SCAS, six types of input files (same as in ASPM/SCAA) are used (Fig. 1).

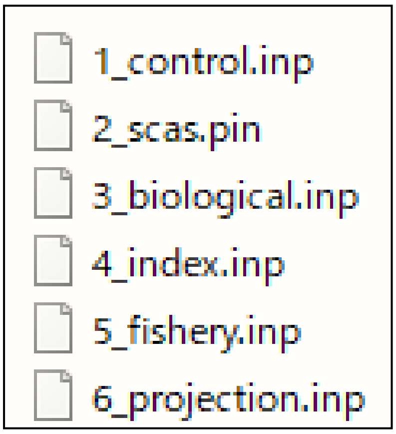


Fig. 1 Six type input files for SCAS

3.1 control.inp

This input file is for basic set ups for SCAS run, i.e.,

Section 0: Just for pre-setting (verbose)
Section 1: Year, age, length and number of fleets
Section 2: Recruitment
Section 3: Dynamics
Section 4: Setting regarding quality/distribution of data
Section 5: Selectivity
Section 6: Phase (negative phase values mean "non-estimated" parameters
Section 7: Likelihood setting

3.2 scas.pin

This input file is for setting up initial seeding values for virgin SSB, initial F, selectivity and others.

3.3 biological.inp

This input is for biological information (steepness, LW relation, natural mortality, growth equation and Maturity-At-Age), which was determined as follows:

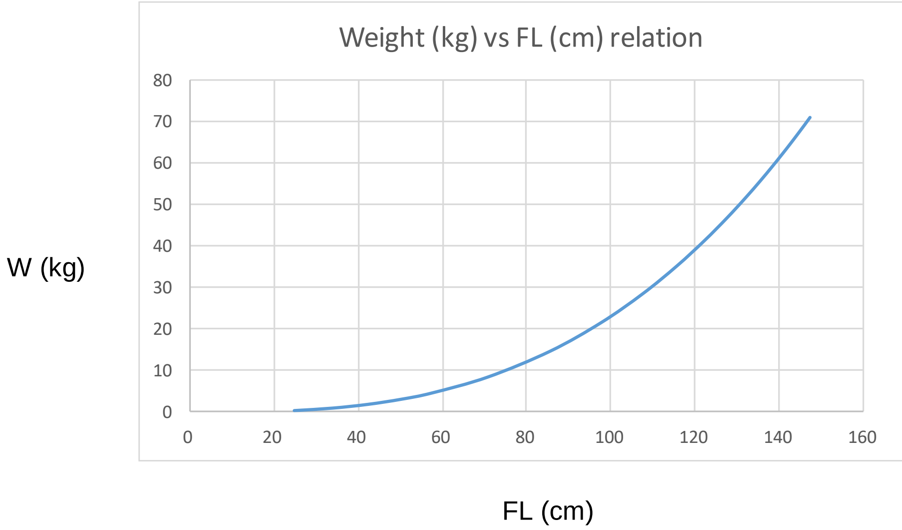
(1) Steepness

We set up 0.8 as a base case and 0.7 and 0.9 as sensitivities.

(2) LW relation (BOX 2)

Box 2 Length-weight relationships (Chassot et al, 2016) (IOTC-2016-WPDSC12-INF05)

$$W(kg) = 2.217*10^{-5}*(FL: cm)^{3.01211}$$

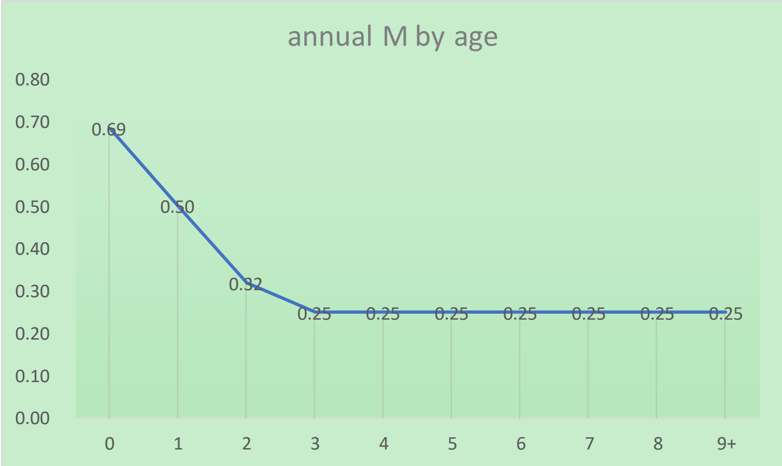


(3) **Natural mortality vector (*M*)**

Langley (2016) applied two alternative levels of age-specific natural mortality. The higher level of natural mortality is comparable to IATTC and WCPFC bigeye tuna stock assessments with relatively high natural mortality for the younger age classes and natural mortality for the adult age classes.

A lower level of natural mortality was proposed based on a Lorenz curve analysis with a lower natural mortality for the adult age classes. This is comparable to the level of natural mortality assumed for Atlantic bigeye tuna in the recent ICCAT stock assessment by (ICCAT, 2015). This relationship between M and age/size (high M for juveniles and low M for adults) are well established for tuna (Hampton 2000) and corresponds well with some of the biological factors contributing to the variability of natural mortality of tuna (Fonteneau and Pallares, 2004). Thus, we use low annual natural mortality as a base case (Box 3).

BOX 3 Annual M vectors by age (based on ICCAT, 2015 derived by the Lorenz curve)



Natural mortality by age

Age	0	1	2	3	4	5	6	7	8	9
M	0.69	0.5	0.32	0.25	0.25	0.25	0.25	0.25	0.25	0.25

(4) Growth equation (Box 4)

Box 4 Indian Ocean BET growth equation (Everson et al, 2012)

Growth curve

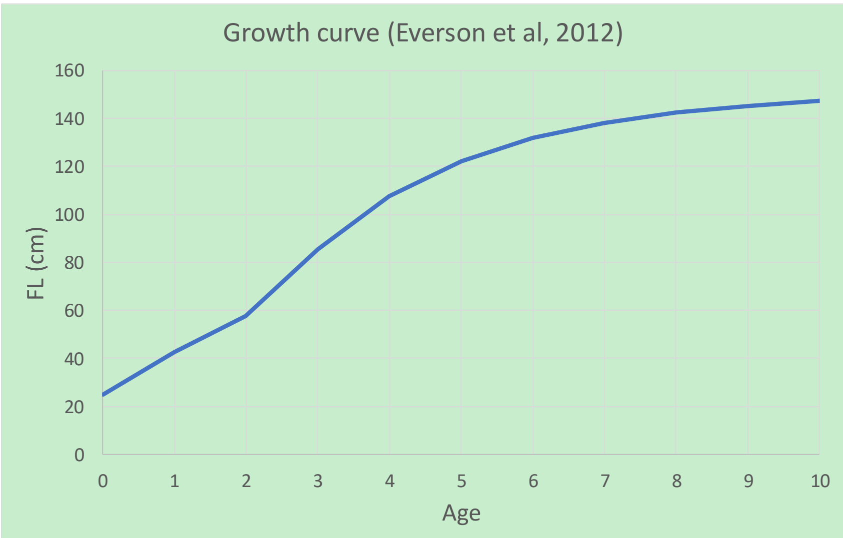
$$l(a) = L_\infty \left[1 - \exp\left(-k_2(a - a_0)\right) \left\{ \frac{1 + \exp\left(-\beta(a - a_0 - \alpha)\right)}{1 + \exp(\alpha\beta)} \right\}^{-(k_2 - k_1)/\beta} \right]$$

l: Length (FL)

a: Age

parameters

$$L_\infty = 150.9, a_0 = -1.2, k_1 = 0.15, k_2 = 0.41, \alpha = 3.4, \beta = 20$$



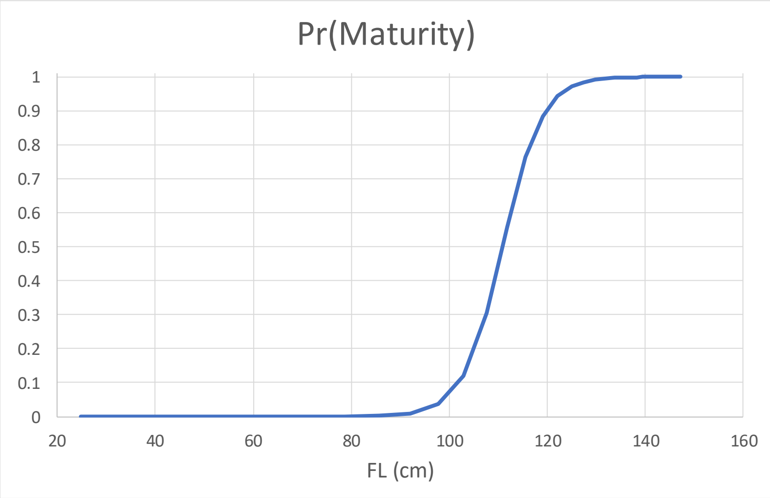
(5) Maturity-at-age (Box 5)

Box 5 Maturity at-age based on Shono et al (2009) and Age-length key (Everson et al, 2012)

Shono et al (2009) assume that age 2 is no maturation and 6 fully matured then derived the equation to compute the probability of maturation by length.

$$Ma(L) = \frac{1}{1+\exp\{-0.25*(L-110.888)\}}$$ Shono et al (2009)

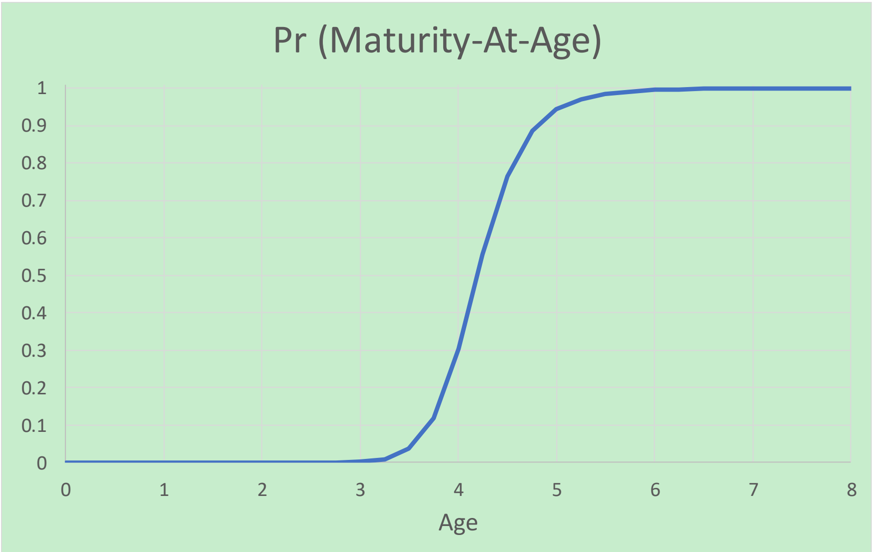
, where Ma(L) is the probability of maturity by size.



Then Ma(L) is converted to age by the growth curve (Everson et al, 2012) and probabilities by age are computed as below:

Proportion maturity by age

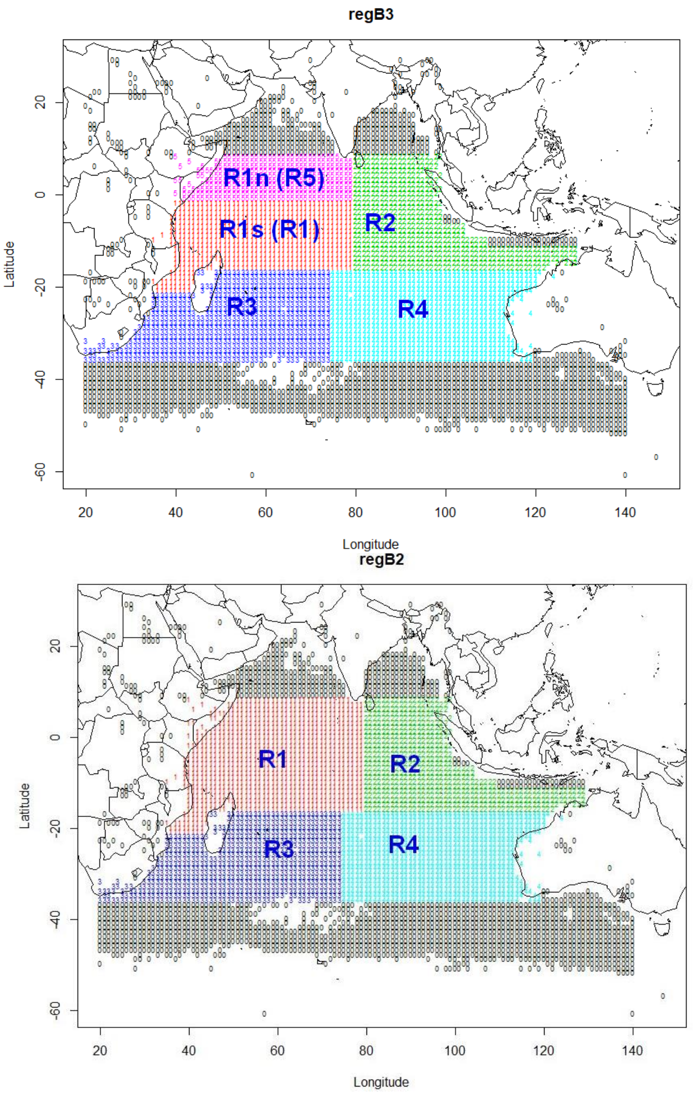
# age	0	1	2	3	(3.5)	4	(4.5)	5	6	7	8	9+
	0	0	0	0.00	0.04	0.30	0.77	0.94	1	1	1	1



3.4 index.inp (CPUE)

We used the joint CPUE (Hoyle et al, 2019) (IOTC-2019-WPM10-16). As SCAS is based on year (season aggerated), we use annual and area based standardized joint CPUE. In the joint CPUE, there are two types of sub-areas in the western tropical region, i.e., (a) split one by two (R1n and R1s) and (b) contiguous one (R1) (BOX 6). We use the contiguous one because we don't have separate information on R1. We further combined R3+R4 as one sub-area because R4 has very low catch.

BOX 6 Sub-araes defined in the joint CPUE(Hoyle et al 2019)
(above) R1 with split by R1n and R1s, (below) R1 as one sub-arae
(note) In SACS, we further combined R3+R4 as one R34.



IOTC Area	Joint CPUE area	Fisheries	Joint CPUE
A1	R1(R1n+R1s)	(1) LL1	Average of R1n+R1s
A2	R2	(2) LL2	R2
A3	R3+R4	(3) LL3	Average of R3+R4

In each area, there are four types of standardized CPUE as shown in Table 3. In the past, type [D] starting from 1979 has been used in yellowfin tuna, bigeye tuna, albacore tuna (2016-2019, IOTC) as vessel ID produced more plausible abundance indices.

Table 3 Four types of joint standardized CPUE (Holye et al 2019)

Type	Attributes	Period	Years
[A]	With vessel ID (later period)	All	1955-2018
[B]	No Vessel ID	Earlier	1956-1979
[C]	No Vessel ID	All	1955-2018
[D]	With vessel ID	Later	1979-2018

In addition, there is a scientific merit to start from 1979. This is because there has been unsolved and pending questions on a large gap before and after 1978/79 (Fig 2), which make stock assessment results very different, i.e., if CPUE for the entire period is used, then the stock status will be more optimistic as CPUE levels raise after 1978/1979, while it will be less optimistic if CPUE after 1978/79 is used as it shows the decreasing trend. We consider that CPUE after 1989/89 is more plausible as caused of the sudden jump in 1978/1979 cannot be explained thus not realistic.

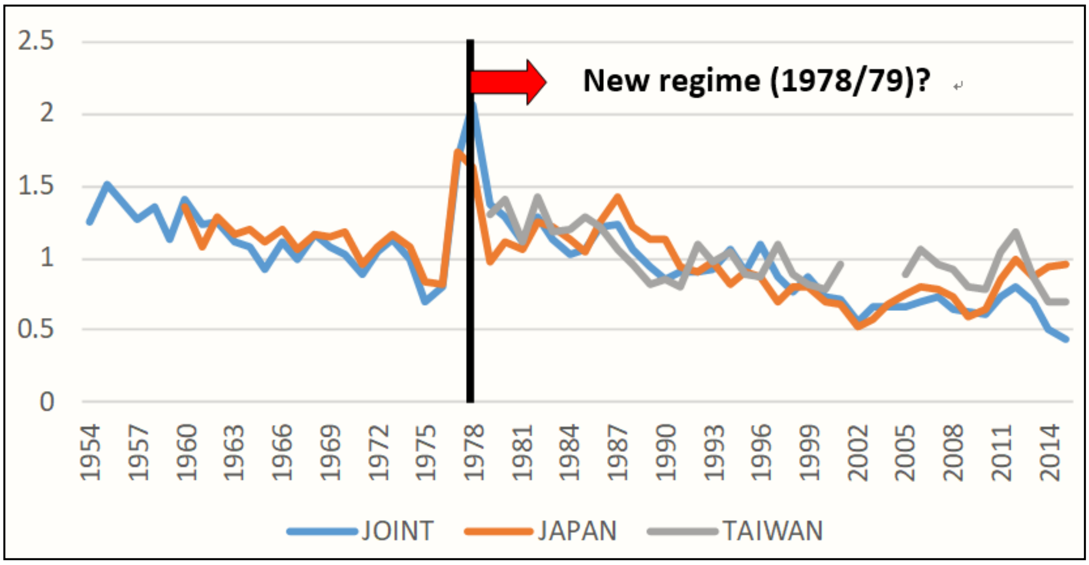


Fig. 2 Unsolved and pending question on the sudden CPUE jumps in 1978/1979 (Nishida et al, 2016)

Catchability increase by gear and boat evolution is not considered (such as 1% increased by year) in our study. Other CPUE such as Indonesian LL (IOTC-2019-WPTT21-31) and others available in the IOTC database are not applied due to time constraint.

Fig 3 shows trends of joint CPUE for 3 IOTC sub areas (A1: WEST, A2: EAST and A3 SOUTH). Three CPUE shows the decreasing trends in general. In recent years, A1(WEST) shows more rapid declining trend than other two.

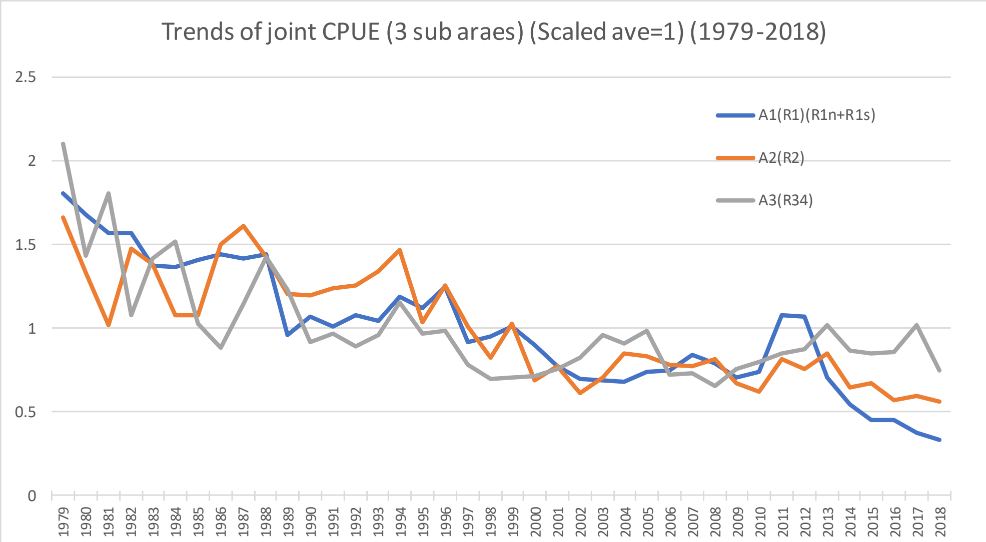
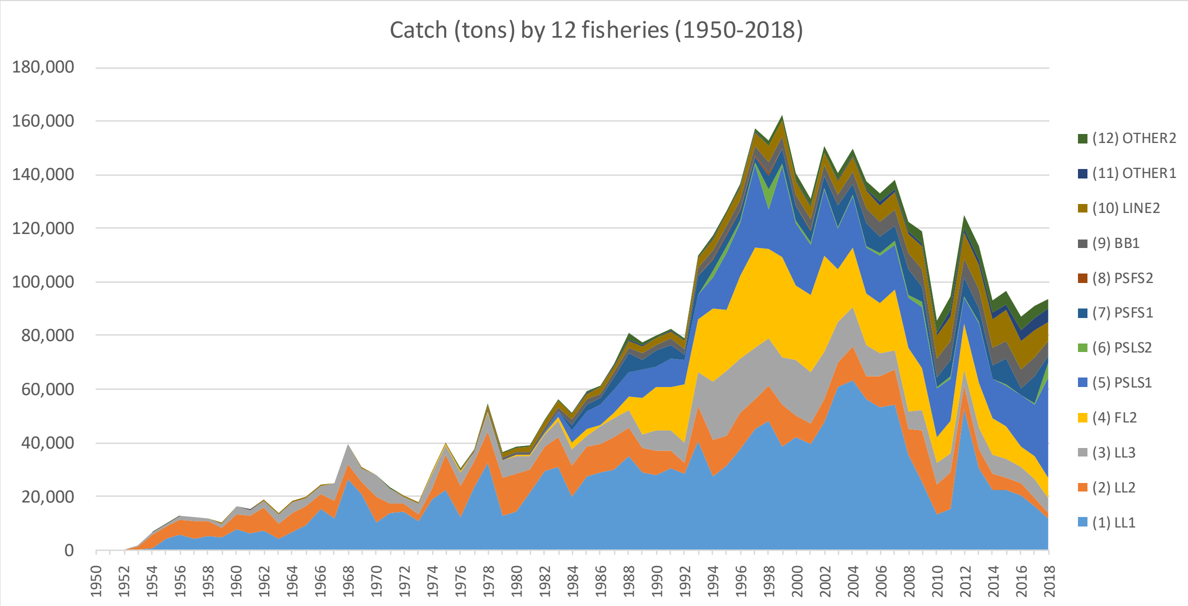


Fig.3 Trends of joint CPUE (3 sub areas) (scaled as Ave=1) (1979-2018)
Note
A1, A2 and A3: IOTC area (Fig 1, p.3)
R1(R1n+R1s), R2 and R34: joint CPUE area (Fig. 2, p.9)

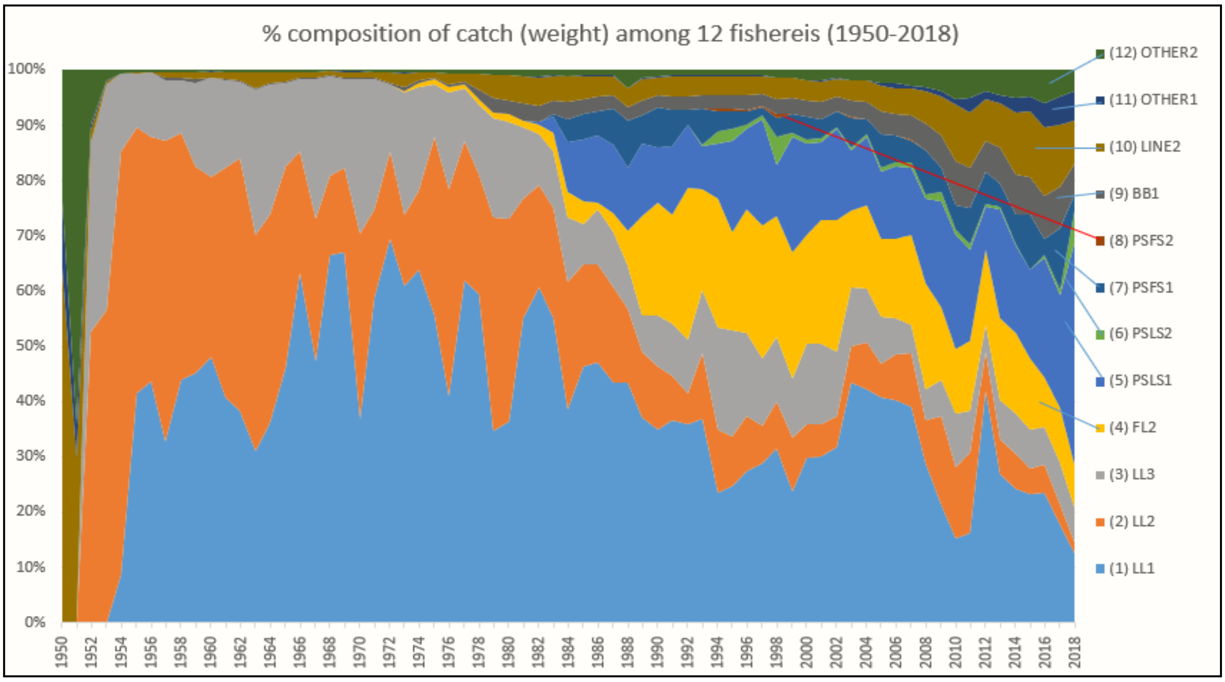
3.5 fishery.inp

This input file is for fishery related information including catch (tons) by fisheries and CAS (based on sample size data) by fisheries. Fig. 4 (a) and (b) shows trends of catch (ton) and its compositions for 12 fisheries used in SCAS.

In general, catch increased 1950's to 1999 (peak, at 162,00 tons), afterwards decreased to 2018 (94,000 tons). In early 1950 - late 1990, major catch was made by four fisheries [LL1(WEST), LL2(EAST) and LL3 (SOUTH)], afterwards by five [LL1(WEST), FL2(EAST), PSLS1(WEST), LL2(WEST) and LL3(SOUTH)].



(a)



(b)

Fig. 4 (a) Trends of catch (tons) and (b) its compositions for 12 fisheries.

3.6 projection.inp

This input file is for the future projections including number of years for projections and catch levels to be projected by 12 fisheries.

4. FUTURE WORKS

Model runs were not completed by the WPTT in 2019. However, there is a difference from SS3; the model tries to estimate the extent of recruitment deviation as well as the relative weight to size/CPUE using an integrated likelihood not using a penalized likelihood. Result of model run will be given for next assessment for ALB and tropical species to compare other stock assessment results. Also, the code will be extended to a use-friendly software (now "exe" files with 6 input files). Update will given in 2020 WPTT.

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