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Update on natural mortality estimators for chub mackerel in the Northwest Pacific Ocean

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Summary

- This working paper (NPFC TWG-CMSA04 WP05) was originally submitted to TWG CMSA04 aiming to update the Von-Bertalanffy growth curve and M estimators, and propose the updated M values to be utilized as an OM setting
- But, the TWG CMSA has determined to continue to use an old M values for OM and re-evaluate M values for the benchmark stock assessment
- Here we present and propose the updated growth parameters and M values again, for the next benchmark stock assessment

Introduction

- Takahashi et al. (2019) submitted working paper about M estimators for chub mackerel to TWG CMSA02 and proposed using the median of various estimators (M = 0.41) and age-specific M based on Gislason estimator

These age-common and age specific Ms were used for the OM testing process

The growth parameters were estimated using limited samples

Age	Length (cm)	*M* values	
		"Gislason1"	"Gislason2"
1	24.8	0.47	0.48
2	28.4	0.38	0.39
3	31.3	0.32	0.34
4	33.7	0.28	0.30
5	35.7	0.26	0.28
6	37.3	0.24	0.26

(Takahashi et al. 2019 NPFC-2019-TWG CMSA02-WP01)

Update of growth curve and M

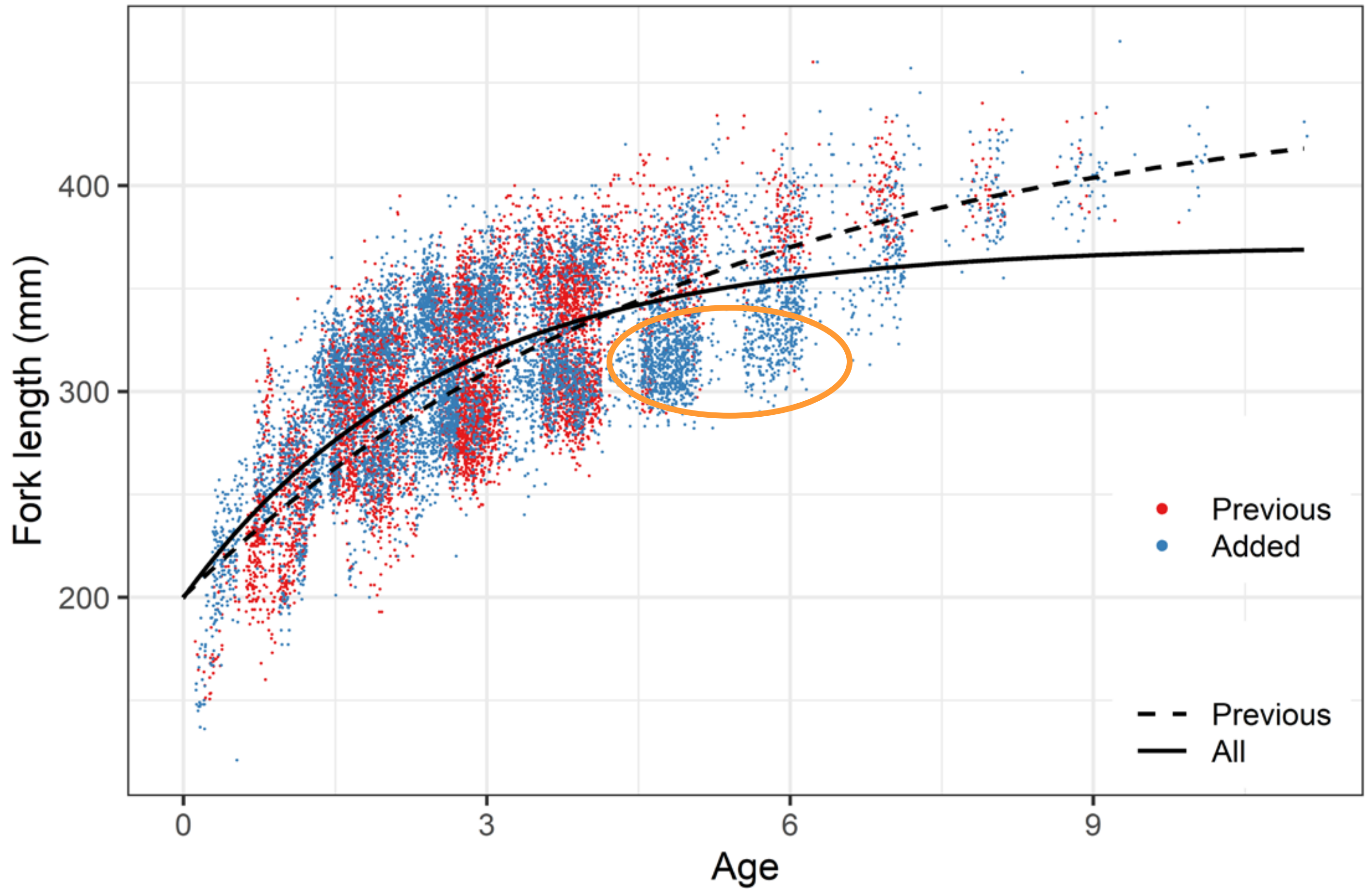
Table 2. Fork length (FL) range, age (t) range, and estimated von Bertalanffy parameters (L_{inf}, K, and t_0) by year class for chub mackerel.

Year class	n	FL range (mm)	t range (years)	L_{inf}	K	t_0
All	15 415	121–470	0.2–11.1	371.0	0.39	−1.96
2006	525	207–426	0.4–8.1	440.5	0.26	−2.25
2007	1 548	188–460	0.3–9.8	400.4	0.49	−1.26
2008	659	226–434	0.6–11.1	396.0	0.50	−1.38
2009	1 315	212–440	0.8–10.1	400.6	0.44	−1.62
2010	1 351	208–470	0.4–9.3	396.5	0.48	−1.59
2011	830	226–455	0.8–8.3	393.5	0.35	−2.88
2012	1 865	121–457	0.3–7.3	360.2	0.55	−1.41
2013	4 522	160–460	0.5–6.7	356.9	0.32	−2.41
2014	1 533	198–430	0.4–5.7	348.4	0.36	−2.37
2015	647	193–420	0.4–4.7	400.5	0.25	−2.23
2016	620	136–358	0.2–3.7	339.9	0.47	−1.29

(Kamimura et al. 2021, ICES JMS)

- Added new data from the previous document
- Updated not only age-specific but also age-common M estimates based on the updated life-history parameters of VB curve

Previous and Updated VB curves



- Previous samples: *N*=7,845
- Added samples: *N* = 7,570
- Added data found smaller fork lengths at age 5 and older
- This is because the deterioration of growth after 2013 year-class due to the density-dependent effect
- Decrease in asymptotic Fork length (L_∞: 44.6→37.1[cm])
- Increase in growth coefficient (*K*: 0.20→0.39)

Update of estimated growth parameters

Table 1: Information on sample data and estimated growth parameters in the previous and updated analyses.

Data	Sample size	Year Class	Sampling Year	FL range (mm)	Age range (years)	L_∞	K	t_0
Analysis ignoring the difference among year classes								
Previous	7845	2006-2015	2006-2018	160-460	0.8-10.2	446	0.2	-3.05
All	15415	2006-2016	2006-2019	121-470	0.2-11.1	371	0.39	-1.96
Analysis incorporating the difference among year classes as random effects								
All	15415	Average	2006-2019	121-470	0.2-11.1	382	0.41	-1.8
-	525	2006	2006-2014	207-426	0.4-8.1	428	0.3	-1.99
-	1548	2007	2007-2017	188-460	0.3-9.8	401	0.49	-1.27
-	659	2008	2008-2019	226-434	0.6-11.1	397	0.48	-1.45
-	1315	2009	2010-2019	212-440	0.8-10.1	401	0.43	-1.63
-	1351	2010	2010-2019	208-470	0.4-9.2	397	0.47	-1.62
-	830	2011	2012-2019	226-455	0.8-8.2	390	0.4	-2.43
-	1865	2012	2012-2019	121-457	0.3-7.2	361	0.54	-1.47
-	4522	2013	2013-2019	160-460	0.5-6.7	355	0.32	-2.34
-	1533	2014	2014-2019	198-430	0.4-5.7	346	0.38	-2.2
-	647	2015	2015-2019	193-420	0.4-4.7	379	0.31	-1.85
-	620	2016	2016-2019	136-358	0.2-3.7	350	0.42	-1.4

- Added new samples (*N* = 7570)
- The growth parameters were greatly changed
- Recent year classes have smaller sample sizes and shorter age ranges (a concern at the SWG OM)
- Conducted a sensitive analysis that incorporate the difference of year classes as a random effect in Appendix and show its result later

Natural mortality estimator equations

The same estimator equations as previous were used

Estimator identifier	Equation	Reference
“Pauly”	$M = 0.9849 L_{\infty}^{-0.279} K^{0.6543} T^{0.4634}$	Pauly (1980)
“Pauly update”	$M = 4.118 L_{\infty}^{-0.33} K^{0.73}$	Then et al., (2015)
“Jensen”	$M = 1.5K$	Jensen (1996)
“Hoenig”	$M = 4.3/A_{max}$	Hoenig (1983)
“Hoenig update”	$M = 4.899 A_{max}^{-0.916}$	Then et al. (2015)
“Gislason1”	$M = 1.73 L^{-1.61} L_{\infty}^{1.44} K$	Gislason et al. (2010)
“Gislason2”	$M = K(L/L_{\infty})^{-1.5}$	Charnov et al. (2013)
“FishLife”	-	Thorson (2020)

Age-common natural mortality

	M value	L_∞	K	T	A_{max}	L	Input data source
“Pauly”	0.72 (0.44)	37.1 (44.6)	0.39 (0.20)	17.0 (16.7)			Kamimura et al. (2021)
“Pauly update”	0.63 (0.36)	37.1 (44.6)	0.39 (0.20)				Kamimura et al. (2021)
“Jensen”	0.59 (0.30)		0.39				Kamimura et
“Hoenig”	0.39 (0.43 & 0.39)						
“Hoenig update”	0.54 (0.59 & 0.54)						al. (2021)
“Gislason1”	0.48 (0.36)	37.1 (44.6)	0.39 (0.20)			31.1 (29.0)	Kamimura et al. (2021)
“Gislason2”	0.51 (0.38)	37.1 (44.6)	0.39 (0.20)			31.1 (29.0)	Kamimura et al. (2021)
“FishLife”	0.48 (0.48)						Frose & Pauly (2000)
Median	0.53 (0.41)						

- M relevant to growth was estimated to be higher
- Mainly because of larger *K*
- Median M was changed from 0.41 to 0.53

Age-specific natural mortality

Age	Length (cm)	M value		
		"Gislason1"	"Gislason2"	Mean
0	22.9	0.79	0.80	0.80
	-	-	-	-
1	27.5	0.59	0.61	0.60
	(24.8)	(0.47)	(0.48)	(0.48)
2	30.6	0.50	0.52	0.51
	(28.4)	(0.38)	(0.39)	(0.39)
3	32.7	0.45	0.47	0.46
	(31.3)	(0.32)	(0.34)	(0.33)
4	34.1	0.42	0.44	0.43
	(33.7)	(0.28)	(0.30)	(0.29)
5	35.1	0.40	0.42	0.41
	(35.7)	(0.26)	(0.28)	(0.27)
6	35.7	0.39	0.41	0.40
	(37.3)	(0.24)	(0.26)	(0.25)

- Age-specific M was calculated based on the middle point of age in year
- Age-specific M was also estimated to be higher due to larger *K*

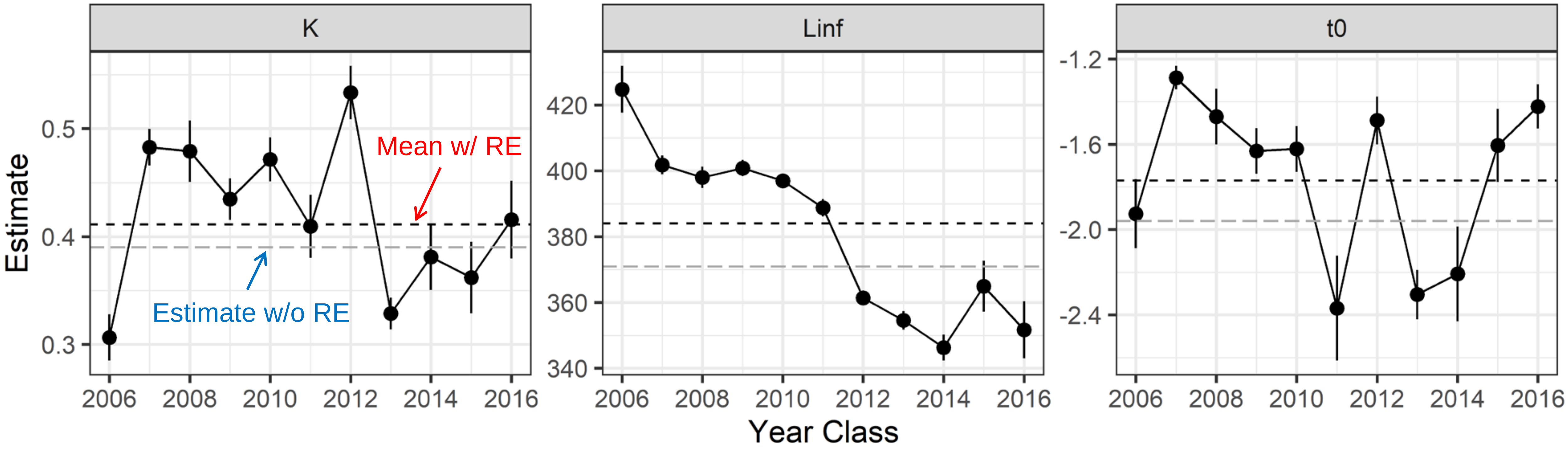
Sensitivity analysis: Effect of year classes

- The growth parameters could vary among year classes (mainly due to stock size; Kamimura et al. 2021)
- The sample size and age range were also different among year classes as previously showed
- These problems might cause biased estimates in the growth parameters and M
- Estimated the growth parameters by incorporating the difference of year classes as random effects (RE)

$$\log L_{\infty,y} \sim Normal(\log L_{\infty}, \sigma_L^2),$$
$$\log K_y \sim Normal(\log K, \sigma_K^2),$$
$$t_{0,y} \sim Normal(t_{0,y}, \sigma_t^2).$$

Mean estimates that should be used for M estimators

Year-to-year growth parameters



- AIC value became much lower by incorporating RE (149580.7 → 134911.9)
- *Linf* had clearly been decreasing
- *K*, the most influential parameter for M, was little different from the value without RE (0.39 → 0.41)

Age-common M in the sensitivity analysis

Table A1: Natural mortality coefficients (*M*) estimators obtained from the life-history parameters estimated by the model that incorporates the difference of the growth parameters. The numbers in the parentheses are estimates from the model without the growth difference among year classes.

	M **value**	L_∞	K	T	A_{max}	L	**Data source**
"Pauly"	0.74 (0.72)	38.2 (37.1)	0.41 (0.39)	17.0 (17.0)			Kamimura et al. (2021)
"Pauly update"	0.65 (0.63)	38.2 (37.1)	0.41 (0.39)				Kamimura et al. (2021)
"Jensen"	0.62 (0.59)		0.41 (0.39)				Kamimura et al. (2021)
"Hoenig"	0.39				11		Iizuka (2002) Kamimura et al. (2021)
"Hoenig update"	0.54				11		Iizuka (2002) Kamimura et al. (2021)
"Gislason1"	0.53 (0.48)	38.2 (37.1)	0.41 (0.39)			31.1 (31.1)	Kamimura et al. (2021)
"Gislason2"	0.56 (0.51)	38.2 (37.1)	0.41 (0.39)			31.1 (31.1)	Kamimura et al. (2021)
"FishLife"	0.48						Frose (1990)
Median	0.55 w/ RE (0.53) w/o RE						

The median value is not so different depending on whether RE is included or not

Age-specific M in the sensitivity analysis

Table A2: Age-specific natural mortality coefficients obtained from the model that incorporates the difference of the growth parameters. The numbers in the parentheses are estimates from the model without the growth difference among year classes.

Age	Length (cm)	*M* value		
		"Gislason1"	"Gislason2"	Mean
0	23.3 (22.9)	0.85 (0.79)	0.86 (0.80)	0.85 (0.80)
1	28.3 (27.5)	0.62 (0.59)	0.64 (0.61)	0.63 (0.60)
2	31.6 (30.6)	0.52 (0.50)	0.54 (0.52)	0.53 (0.51)
3	33.9 (32.7)	0.46 (0.45)	0.49 (0.47)	0.48 (0.46)
4	35.3 (34.1)	0.43 (0.42)	0.46 (0.44)	0.45 (0.43)
5	36.3 (35.1)	0.41 (0.40)	0.44 (0.42)	0.43 (0.41)
6	36.9 (35.7)	0.40 (0.39)	0.43 (0.41)	0.42 (0.40)

Note: The necessary life-history parameters of L_∞ and K are shown in Tables 1 and A1.

The M values became slightly higher with RE especially for younger age

Conclusions and Recommendation

- Many M estimators exhibited higher values than in the previous estimators due to a higher growth coefficient of fork length
- Little impact of incorporating the difference of year classes as RE on the M estimators
- Recommend using the results with no RE as the basecase in the next benchmark stock assessment: the median of various updated estimators as the age-common M (0.53) and the mean between Gislason1 and Gislason2 as the age-specific M (0.80 for age 0, 0.60 for age1, 0.51 for age 2, 0.46 for age 3, 0.43 for age 4, 0.41 for age 5, and 0.40 for age 6+)

Age class	0	1	2	3	4	5	6+
Age-common	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Age-specific	0.80	0.60	0.51	0.46	0.43	0.41	0.40