Annex 1: Assessment models developed and evaluated during the Jack Mackerel Subgroup Meeting

Viña del Mar

Data

During the meeting, several new pieces of information were presented. The meeting agreed on data sets going forward for catch (Table 1). The detailed catch-age and index data can be provided by the SPRFMO Secretariat. The subgroup evaluated the treatment of the length frequency data for the early period (1979-1991; Fig. 1) relative to how age determinations used to convert these data to ages affect the age compositions. The mean weights-at-age over time used for all gear types and indices, as decided by the ASTT, is provided in Fig. 2 and maturity-at-age is shown in Table 2. The final datasets evaluated by the subgroup are available to members upon request.

Assessment models

TISVPA Model

A "triple-separable" version of the ISVPA model (TISVPA) was used for the assessment runs. This version of the model allows it to take into consideration possible cohort-dependent peculiarities in selection pattern originating from different interactions of different cohorts with fishing fleet, or by possible errors in aging of some cohort or by some other unknown reasons. The catch-at age data of all fleets were summarized. The common weight-at-age values were found by weighting according to the share of the fleet in the total catches.

The non-mixed version of the model was used. Other settings of the model were the following: unbiased separable representation of fishing mortalities and the split selection pattern for two periods - before and after the 1991.

The model settings were chosen to minimize non-contradicting signals from the available catch-at-age data. No additional fitting data were applied and the following settings were used:

- The "catch-controlled" version (catch-at-age is assumed as true and all residuals in catch-at-age are attributed to violations of selection pattern stability) with the assumption of unbiased separable representation of fishing mortalities;
- The window for estimation of cohort-factors – from age 3 to age 10; the measure of closeness of fit for catch-at-age – sum of squared residuals in logarithmic catches;
- The absolute median deviation (AMD) was used to minimize the residuals in the given and estimated catches-at-age.

The year of the change in selection pattern was chosen as 1991.

Joint jack mackerel model

A statistical catch-at-age model was used to evaluate the jack mackerel stock. The JJM ("Joint Jack Mackerel Model") considered different types of information, which corresponds to the available data of the jack mackerel fishery developed on the South Pacific area since 1970 to 2010. A list of this information is listed in Table 3.

Parameters estimated conditionally are listed in Table 4. The most numerous of these involve estimates of annual and age-specific components of fishing mortality for each year from 1970-2010 and each of the four fisheries identified in the model. Parameters describing population numbers at age 2 in each year (and years prior to 1970 to estimate the initial population numbers at ages 2-12) were the second most numerous type of parameter.

The table of equations for the assessment model is given in Tables 5, 6 and 7.

The treatment of selectivities and how they are shared among fisheries and indices is given in Table 8. The numbers of parameters for different model configurations were around 350. Also depending on the model configuration, some growth functions were employed to convert length compositions to age compositions (see Table 9)

Model evaluation

A set of 7 exploratory models were proposed and run for evaluation purposes. The assessment considered 7 model configurations and their detail are showed in Table 10. The last three models 5,6 and 7 (which were based on model 4) correspond to sensitivity analysis, which ocused on evaluating the model response when the weight of abundance indexes is changed, or a different value of natural mortality is used. These specifications are shown in Table 11. The subgroup evaluated the impact of different configurations and selected Model 4 as the “base case” for the work presented in Annex 2, based on comparison of likelihood values shown in Table 12.

References

Gili, R., L. Cid, V. Bocic, V. Alegría, H. Miranda & H. Torres. 1995. Determinación de la estructura de edad del recurso jurel. In: Estudio biológico pesquero sobre el recurso jurel en la zona centro-sur, V a IX Regiones. Informes Técnicos FIP/IT-93-18.

Kochkin, P.N., 1994. Age determination and estimate of growth rate for the Peruvian jack mackerels, Trachurus symmetricus murphyi. J. of Ichthyol. 34(3): 39-50.

Figures

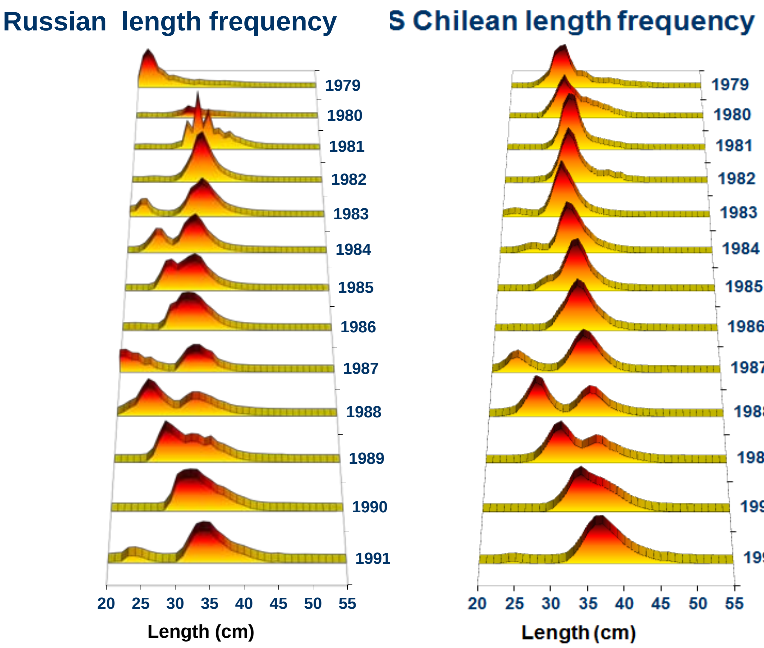

Figure 1. Historical 1979 – 1991 length frequency distributions for the Russian and south-central Chilean fisheries.

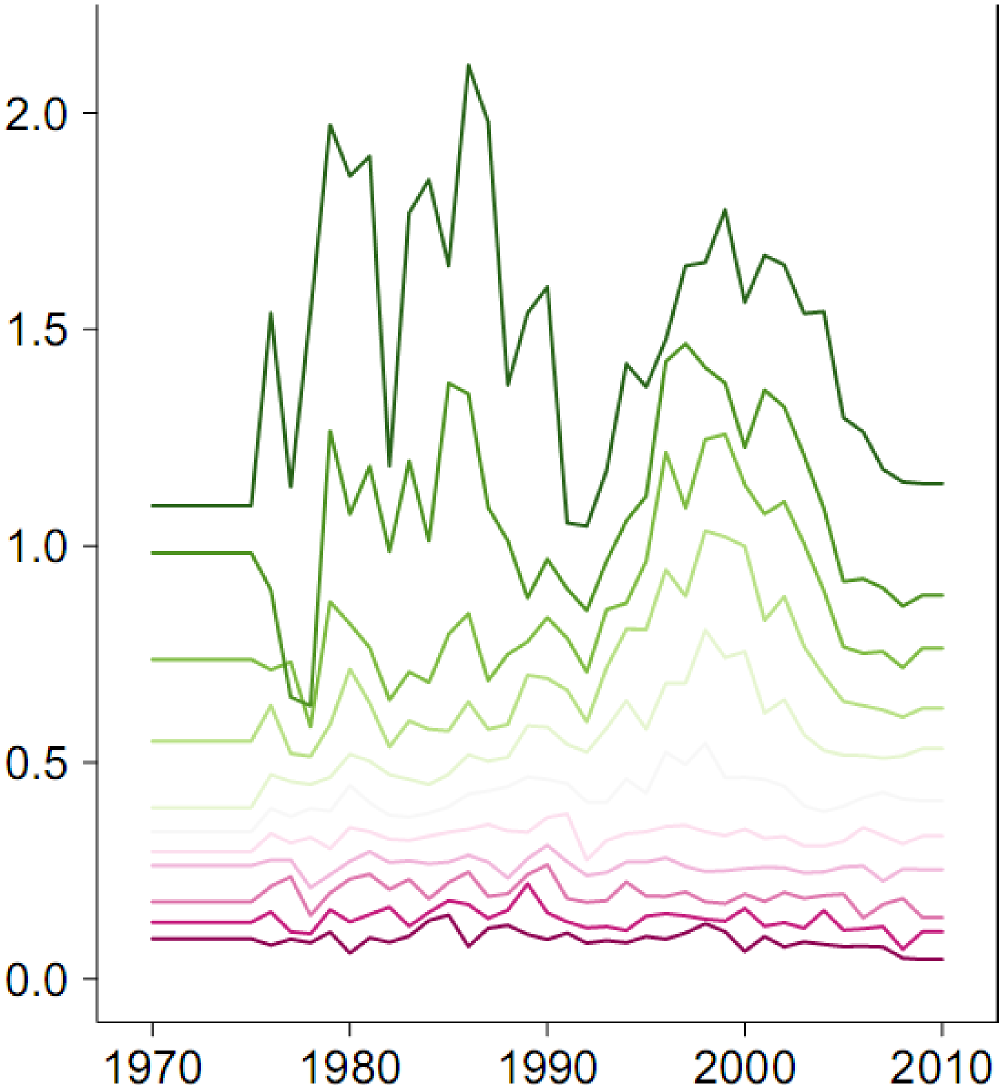

Figure 2. Mean weights-at-age (kg) over time used for all data types in the JJM models. Different lines represent ages 2 to 12.

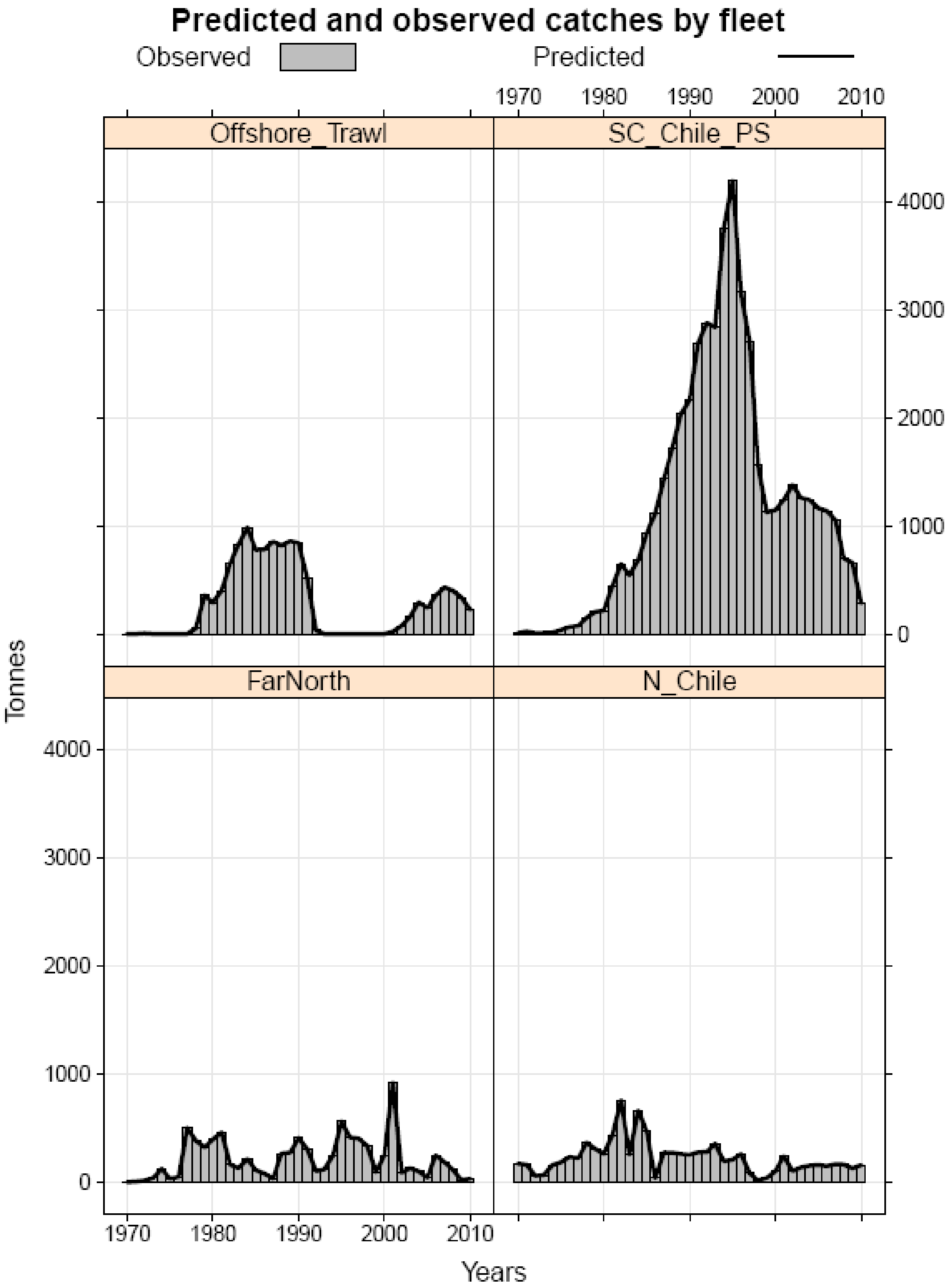

Figure 3. JJM Model fit to the total catches ('000 tonnes) by fleet for Fleet 1 (N_Chile_PS), Fleet 2 (SC_Chile_PS), Fleet 3 (Far_North) and Fleet 4 (Offshore_Trawl). The bars represent the observations and the line represents the predicted values.

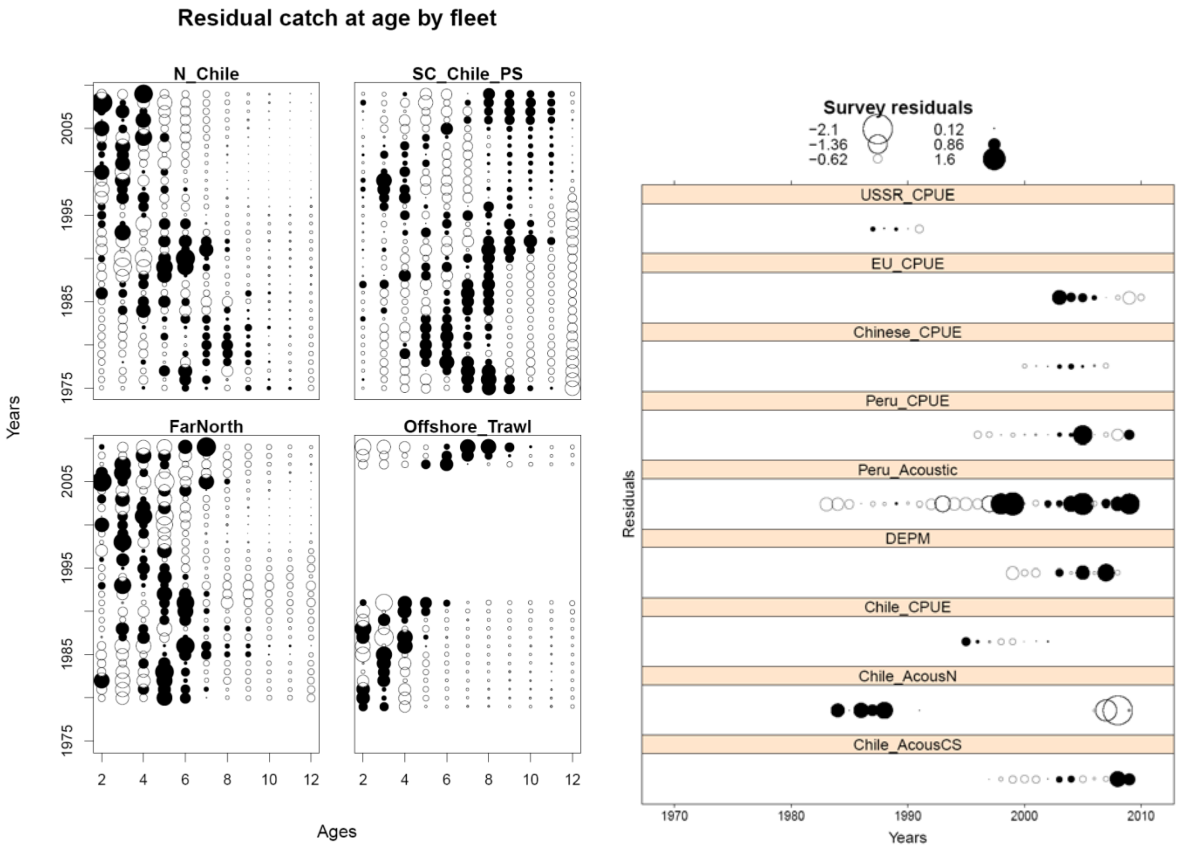

Figure 4. Logged residuals of observed and predicted catch-at-age proportions for the different fleets (left) and residuals for each of the indices (right) from JJM model 4.

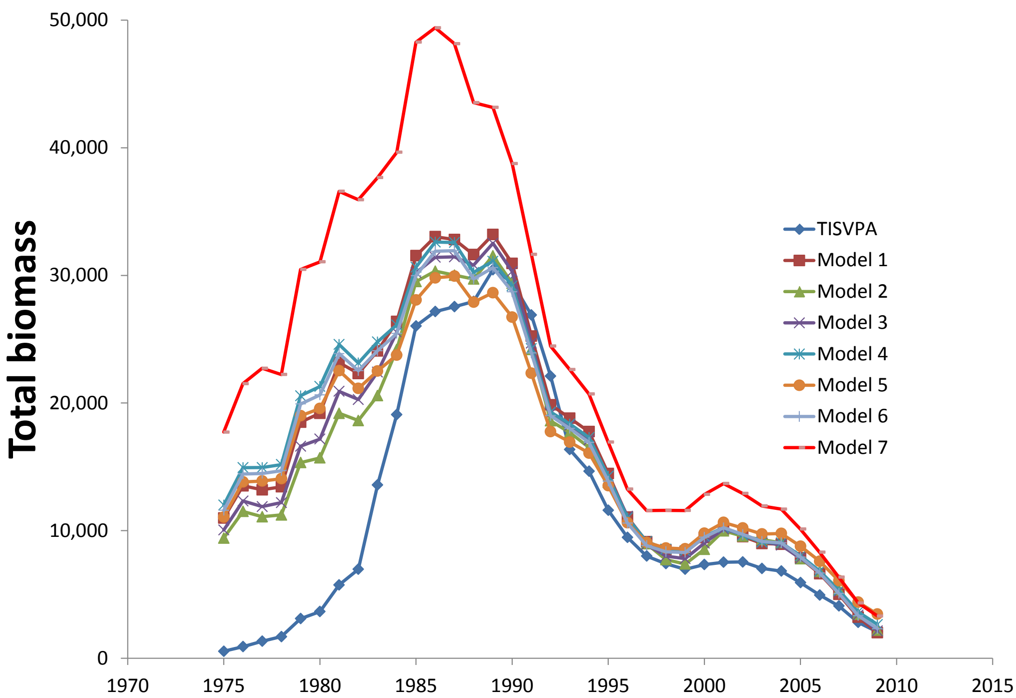

Figure 5. Total biomass estimates comparing the TISVPA model to that of the seven JJM models.

Table 1. Sources and values of catch (t) compiled for the four fleets used for the assessment. 1) data provided by Chilean scientists, 2) fraction of catches reported to SPRFMO that was assigned by working group to fleet 2. 2010 data are provisional.

	Fleet 1	**Fleet 2**	**Fleet 3 (Far north)**					**Fleet 4 Trawler fleet off Chile (outside EEZ)**									
Year	N Chilea (1)	Chile CS (1)	Peru(1)	Ecuado (2)	USSR	Cuba (2)	Total fleet 3	Belize	China	EU	Faroe I.	Korea	Russia/USSR 1)	Cuba	Vanuatu	Fleet 4	Grand total
1970	175208	7938	4711				4711									0	187857
1971	164838	21934	9189				9189									0	195961
1972	62634	7100	18782				18782						5500			5500	94016
1973	71762	8904	42781				42781									0	123447
1974	163396	12678	129211				129211									0	305285
1975	186890	34951	37899				37899									0	259740
1976	237876	65570	54154				54154									0	357600
1977	225907	75585	504992				504992									0	806484
1978	367762	150319	386793				386793						49220			49220	954094
1979	311682	203269	151591		175938		327529						356271			356271	1198751
1980	266697	215528	123380		252078	21885	397343						292892	0		292892	1172460
1981	435061	440935	37875		371981	55598	465454						399649	0		399649	1741099
1982	756484	643821	50013		84122	32401	166536						651776	0		651776	2218617
1983	259128	541696	76825		31769	26876	135470						799884	29480		829364	1765658
1984	663695	677910	188893		15781	10510	215184						942479	39623		982102	2538891
1985	471599	923042	79370		26089	12049	117509						762903	13204		776106	2288256
1986	42536	1103200	44292		1100	40282	85674						783900	0		783900	2015310
1987	280594	1416781	38099			0	38099						818628	40413		859041	2594515
1988	278701	1703037	113743		120476	35890	270109						817812	0		817812	3069659
1989	265861	2031058	133671		137033	9264	279968						854020	4635		858655	3435542
1990	258233	2150956	224684	4144	168636	14312	411776						837609	4710		842319	3663284
1991	282817	2649828	234110	45313	30094	507	310024						514534	0		514534	3757203
1992	285387	2796812	93065	15022		0	108087						32000			32000	3222286
1993	359947	2745099	121309	2673		0	123982									0	3229028
1994	197414	3596904	213220	36575			249795									0	4044113
1995	211594	3984244	386748	174393			561141									0	4756979
1996	264631	3017165	357953	56782			414735									0	3696531
1997	88276	2541981	371485	30302			401787									0	3032044
1998	19278	1546704	314123	25900			340023									0	1906005
1999	44582	1130488	82541	19072			101613									0	1276683
2000	107769	1135082	240881	7122			248003									0	1490854
2001	244019	1216754	774603	133969			908572		20090							20090	2389435
2002	108727	1357185	92470	604			93074		76261							76261	1635247
2003	142016	1272302	134975				134975		94690			2010	7540		53959	158199	1707492
2004	157647	1289820	106270				106270		131020			7438	62300		94685	295443	1849180
2005	165552	1248971	46769				46769	867	143000	6179		9126	7040		77356	243568	1704860
2006	154524	1215738	256318				256318	481	160000	62137		10470			129535	362623	1989203
2007	170220	1119713	188450	927			189377	12585	140582	123511	38700	10940			112501	438819	1918129
2008	167258	728850	120749				120749	15245	143182	106665	22919	12600	4800		100066	405477	1422334
2009	133994	690610	25472				25472		117963	112231	20213	13759			79942	344108	1194184
2010*	162371	288048	37413				37413	2240	62159	75747	11643	8183	17493		46487	223952	711784

Table 2. Jack mackerel sexual maturity by age used in the JMM models (SP-07-SWG-JM-SA-05).

Age (yr)	2	3	4	5	6	7	8	9	10	11	12
Proportion mature	0.00	0.04	0.50	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Years and types of information used in the JJM assessment models.

Fleet	Catch at age	Catch at length	Landings	CPUE	Acoustic	DEPM
North Chile purse seine	1975-2009	-	1970-2010	-	1984-1988; 1991; 2006-2009	1999-2008
South-central Chile purse seine	1975-2009	-	1970-2010	1995-2002	1997-2009	-
FarNorth	-	1980-2009	1970-2010	1996-2009	1983-2009	-
International trawl off Chile	1979-1991	2007-2008	1978-2010	China (2000-2007); EU & Vanuatu (2003-2010); exUSSR (1987-1991)	-	-

Table 4. Symbols and definitions used for model equations

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: i = {1970, …., 2010}	i	
Age index: j = { 2, 3, …, 12^+}	j	
Mean weight in year t by age j	$W_{t,j}$	
Maximum age beyond which selectivity is constant	*Maxage*	Selectivity parameterization
Instantaneous Natural Mortality	M	Fixed M=0.23, constant over all ages
Proportion females mature at age j	p_j	Definition of spawning biomass
Sample size for proportion in year i	T_i	Scales multinomial assumption about estimates of proportion at age
Survey catchability coefficient	q^s	Prior distribution = lognormal(μ_q^s , σ_q^2)
Stock-recruitment parameters	R_0	Unfished equilibrium recruitment
	h	Stock-recruitment steepness
	σ_R^2	Recruitment variance
Unfished biomass	φ	Spawning biomass per recruit when there is not fishing
Estimated parameters		
$\phi_i(\#), R_0, h, \varepsilon_i(\#), \mu^f, \mu^s, M, \eta_j^s(\#), \eta_j^f(\#), q^s(\#)$		

Note that the number of selectivity parameters estimated depends on the model configuration.

Table 5. Variables and equations describing implementation of the joint jack mackerel assessment model (JJM).

Eq	Description	Symbol/Constraints	Key Equation(s)
1)	Survey abundance index (s) by year (Δ^s represents the fraction of the year when the survey occurs)	I_i^s	$I_i^s = q^s \sum_{j=2}^{12} N_{ij} W_{ij} S_j^s e^{-\Delta^s Z_{ij}}$
2)	Catch biomass by year	C_i	$\hat{C}_{ij}^f = \sum_{j=2}^{12} N_{ij} W_{ij} \frac{F_{ij}^f}{Z_{ij}} (1 - e^{-Z_{ij}})$
3)	Proportion at age j, in year i	P_{ij}, $\sum_{j=2}^{12} P_{ij} = 1.0$	$p_{ij}^f = \frac{\hat{C}_{ij}^f}{\sum_j \hat{C}_{ij}^f}$ $p_{ij}^s = \frac{N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}{\sum_j N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}$
4)	Initial numbers at age	j = 2	$N_{1970,j} = e^{\mu_R + \varepsilon_{1970}}$
5)		2 < j < 11	$N_{1970,j} = e^{\mu_R + \varepsilon_{1971-j}} \prod_{j=1}^{j} e^{-M}$
6)		j = 12+	$N_{1970,12} = N_{1970,11} \left(1 - e^{-M}\right)^{-1}$
7)	Subsequent years (i >1970)	j = 2	$N_{i,2} = e^{\mu_R + \varepsilon_i}$
8)		2 < j < 11	$N_{i,j} = N_{i-1,j-1} e^{-Z_{i-1,j-1}}$
9)		j = 12+	$N_{i,12^+} = N_{i-1,11}\, e^{-Z_{i-1,10}} + N_{i-1,12}\, e^{-Z_{i-1,11}}$
10)	Year effect and individuals at age 2 and i = 1958, …, 2010	$\varepsilon_i, \sum_{i=1958}^{2010} \varepsilon_i = 0$	$N_{i,2} = e^{\mu_R + \varepsilon_i}$
11)	Index catchability		$q_i^s = e^{\mu^s}$
	Mean effect	μ^s, μ^f	$s_j^s = e^{\eta_j^s}$ $j \le$ maxage
	Age effect	$\eta_j^s, \sum_{j=2}^{12^+} \eta_j^s = 0$	$s_j^s = e^{\eta_{\text{maxage}}^s}$ $j >$ maxage
12)	Instantaneous fishing mortality		$F_{ij}^f = e^{\mu^f + \eta_j^f + \phi_i}$
13)	Mean fishing effect	μ^f	
14)	Annual effect of fishing mortality in year i	$\phi_i, \sum_{i=1970}^{2010} \phi_i = 0$	
15)	age effect of fishing (regularized) In year time variation allowed	η_{ij}^f, $\sum_{j=2}^{12^+} \eta_{ij} = 0$	$s_{ij}^f = e^{\eta_j^f}$, $j \le$ maxage; $s_{ij}^f = e^{\eta_{\text{maxage}}^f}$ $j >$ maxage
	In years where selectivity is constant over time	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \ne$ change year
16)	Natural Mortality	M	Set fixed at 0.23 in basecase
17)	Total mortality		$Z_{ij} = \sum_f F_{ij}^f + M$
17)	Spawning biomass (note spawning taken to occur at mid of November)	Bi	$B_i = \sum_{j=2}^{12} N_{ij} e^{-\frac{10,5}{12} Z_{ij}} W_{ij} p_j$
18)	Recruitments (Beverton-Holt form) at age 2.	$\tilde{R}_i$	$\tilde{R}_i = \frac{\alpha B_i}{\beta + B_i}$, $\alpha = \frac{4hR_0}{5h-1}$ and $\beta = \frac{B_0(1-h)}{5h-1}$ where $B_0 = R_0 \varphi$, $\varphi = \sum_{j=2}^{12} e^{-M(j-1)} W_j p_j + \frac{e^{-12M} W_{12} p_{12}}{1 - e^{-M}}$ h=0.8

Table 6. Specification of objective function that is minimized (i.e., the penalized negative of the log-likelihood).

	Likelihood /penalty component		Description / notes
19)	Abundance indices	$L_1 = \sum_s \lambda_1^s \sum_i \ln\left(\frac{I_i^s}{\hat{I}_i^s}\right)^2$	Survey abundances
20)	Prior on smoothness for selectivities	$L_2 = \sum_l \lambda_2^l \sum_{j=2}^{12^+}\left(\eta_{j+2}^l + \eta_j^l - 2\eta_{j+1}^l\right)^2$	Smoothness (second differencing), Note: *l={s*, or *f}* for survey and fishery selectivity
21)	Prior on recruitment regularity	$L_3 = \lambda_3 \sum_{i=1958}^{2010} \varepsilon_i^2$	Influences estimates where data are lacking (e.g., if no signal of recruitment strength is available, then the recruitment estimate will converge to median value).
22)	Catch biomass likelihood	$L_4 = \sum_f \lambda_4^f \sum_{i=1970}^{2010} \ln\left(\frac{C_i^f}{\hat{C}_i^f}\right)^2$	Fit to catch biomass in each year
23)	Proportion at age likelihood	$L_5 = -\sum_{l,i,j} T_i^l P_{ij}^l \ln\left(\hat{P}_{ij}^l\right)$	*l={s, f}*for survey and fishery age composition observations
24)	Fishing mortality regularity	F values constrained between 0 and 5	(relaxed in final phases of estimation)
25)	Recruitment curve fit	$L_6 = \lambda_6 \sum_{i=1977}^{2010} \ln\left(\frac{N_{i,2}}{\tilde{R}_i}\right)^2$	Conditioning on stock-recruitment curve over period 1977-2004.
26)	Priors or assumptions	R_0 non-informative σ_R^2 fixed at 0.6	
27)	Overall objective function to be minimized	$\dot{L} = \sum_k L_k$	

Table 7. Penalties used on log-likelihood functions in the base model.

L	*s*	Abundance index	$\lambda^{s\ (1)}$	*L*	*f*	Catch biomass likelihood	$\lambda^{f\ (1)}$
1	1	Acoustic CS- Chile	5.6	4	1	N-Chile	200
	2	Acoustic N-Chile	2		2	CS- Chile	200
	3	CPUE – Chile	12.5		3	Peru	200
	4	DEPM – Chile	3.1		4	International	200
	5	Acoustic-Peru	5.6		5	ex USSR	200
	6	CPUE – Peru	12.5				
	7	CPUE- China	3.1				
	8	CPUE-EU	12.5				
	9	CPUE- ex USSR	12.5				
2	*s*	Smoothness for selectivities	$\lambda^{s\ (1)}$	5	*s*	Proportion at age likelihood	T^s
	1	Acoustic CS- Chile	100		1	Acoustic CS- Chile	30
	2	Acoustic N-Chile	100		2	DEPM – Chile	20
	3	CPUE – Chile	100				
	7	CPUE- China	100				
	8	CPUE-EU	100				
	9	CPUE ex-USSR	100				
	f	Smoothness for selectivities	$\lambda^{f\ (1)}$	6	*f*	Proportion at age likelihood	T^f
	1	N-Chile	1		1	N-Chile	20
	2	CS- Chile	25		2	CS- Chile	50
	3	Peru	12.5		3	Peru	30
	4	Internacional	12.5		4	Internacional	30
	5	ex – USSR	12.5		5	ex - USSR	30
3		Recruitment regularity	$\lambda^{s\ (1)}$			S-Recruitment curve fit	$\lambda^{(1)}$
			1.4				1.4

(1) λ corresponds to $0.5/\sigma^2$:

σ	λ
0.05	200.0
0.10	50.0
0.20	12.5
0.30	5.6
0.40	3.1
0.50	2.0
0.60	1.4

Table 8. Description of JJM model components and how selectivity was treated.

Item	Description	Selectivity assumption
Fisheries		
1)	Chilean northern area fishery	Estimated from age composition data
2)	Chilean central and southern area fishery	Estimated from age composition data
3)	Peruvian fishery	Estimated from transformed length data to age.
4)	Recent offshore trawl fishery and	Estimated from recent age composition data (post 1992)
	Ex-USSR trawl fishery	Estimated from historical age composition data.
Index series		
5)	Acoustic survey in central and southern Chile	Estimated from age composition data
6)	Acoustic survey in northern Chile	Assumed to be the same as 1)
7)	Central and southern fishery CPUE	Assumed to be the same as 2)
8)	Egg production survey	Estimated from age composition data
9)	Acoustic survey in Peru	Assumed to be the same as 3)
10)	Peruvian fishery CPUE	Assumed to be the same as 3)
11)	Chinese fleet CPUE (from FAO workshop)	Assumed to be the same as 4)
12)	Vanuatu & EU fleets CPUE	Assumed to be the same as 4)
13)	ex-USSR CPUE	Assumed to be the same as 4) but for earlier period

Table 9. Growth parameters employed to convert the length compositions (Peru) to age compositions for the Fleet 3 far north fishery.

Parameter	Peru (Unpublished)	Russia (Kochkin, 1994)	Chile (Gili et al, 1995)
Loo (cm)	68.8	74.2	70.8
k (year-1)	0.165	0.11	0.094
to (year)	-0.902	-0.89	-0.896

Table 10. Particular specifications for the different models applied.

Model	Description
Initial base case Model 1	• All indices assumed proportional to biomass • Soviet age compositions based on Soviet age-length keys • Include all index data • Gili growth parameters to convert length frequencies from the far-north fishery to age compositions
Sensitivities	
Model 2	Peruvian growth parameters to convert length frequencies from the far-north fishery to age compositions
Model 3	Kochkin growth parameters to convert length frequencies from the far-north fishery to age compositions
Model 4	Soviet age compositions based on Chilean age-length keys
Model 5	Downweight acoustic indices (Double CV)
Model 6	Downweight CPUE data (Double CV)
Model 7	Natural mortality alternative: M=0.33

Table 11. Different cases (coefficients of variation) considered on the sensitivity analysis

Index	n *	model 4 (base case)	model 5	model 6	model 7
Acoustic Chile CS	13	0.2	0.4	0.2	0.2
Acoustic Chile N	10	0.5	1.0	0.5	0.5
CPUE Chile	8	0.2	0.2	0.4	0.2
DEPM Chile	9	0.5	0.5	0.5	0.5
Acoustic Peru	27	0.2	0.4	0.2	0.2
CPUE Peru	14	0.2	0.2	0.4	0.2
CPUE China	8	0.4	0.4	0.8	0.4
CPUE Vanuatu & EU (**)	8	0.25 (2003-06) 0.20 (2007-10)	0.25 (2003-06) 0.20 (2007-10)	0.50 (2003-06) 0.40 (2007-10)	0.25 (2003-6) 0.20 (2007-10)
CPUE USSR	5	0.25	0.25	0.5	0.25
M		0.23	0.23	0.23	0.33

Notes:
* number of observations
** between parenthesis the years

Table 12. Values of components of the objective function for the 7 different JJM models. Note that Model 5 and Model 6 values use different weightings for indices and hence are not strictly comparable.

	Model1	Model2	Model3	Model4	Model5	Model6	Model7
Data							
Indices likelihoods	425.7	409.4	423.4	435.2	222.2	361.0	428.4
Fishery Age compositions	945.0	945.1	965.7	838.2	788.6	828.1	791.6
Survey age compositons	132.8	127.3	133.3	136.5	124.4	133.5	138.6
Catch biomass	6.9	3.7	5.2	6.8	2.0	5.2	5.8
Priors							
Fishery selectivity	50.2	59.2	55.2	31.8	30.6	31.5	30.5
Indices selectivity	24.0	24.7	24.1	26.4	21.1	26.1	27.5
Stock-recruitment	39.1	42.1	38.3	21.0	22.8	24.9	14.4
total	1,623.9	1,611.7	1,645.3	1,496.2	1,212.0	1,410.7	1,437.1