

Annex 1: Models developed and evaluated during the technical 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

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 the 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 splitted 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. The shape of the biomass curve obtained and biomass estimated were similar to the ones of the other model.

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 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 and depending on the case, 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 cases correspond to sensitivity analysis, which was focused on evaluate the model response when the weight of abundance indexes is changed, and a different value of natural mortality.

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. Part of the basis for this is provided 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

Russian length frequency

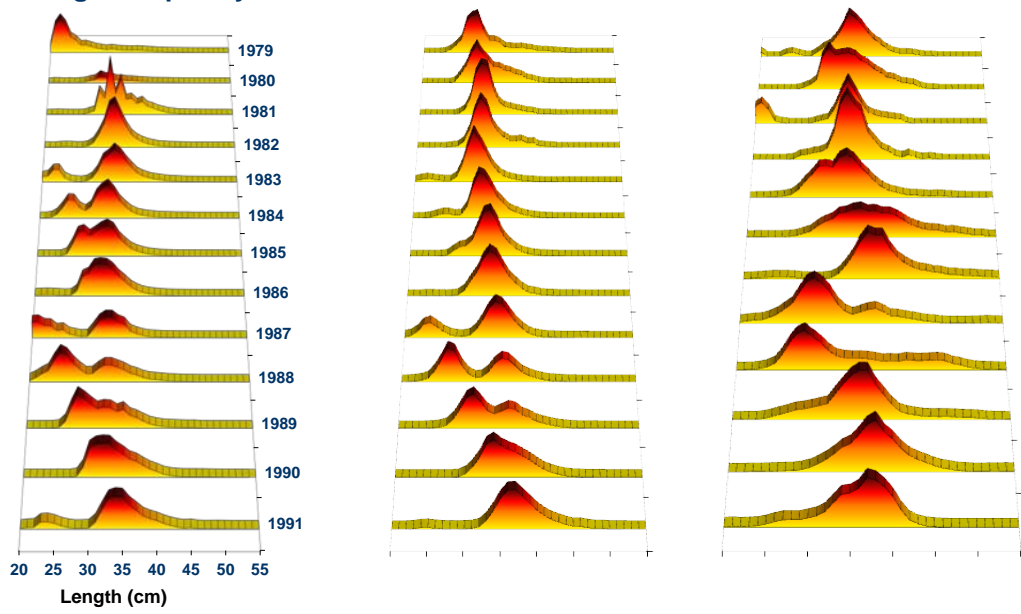


Figure 1. Model fit to the total catches by fleet. The bars represent the observations.

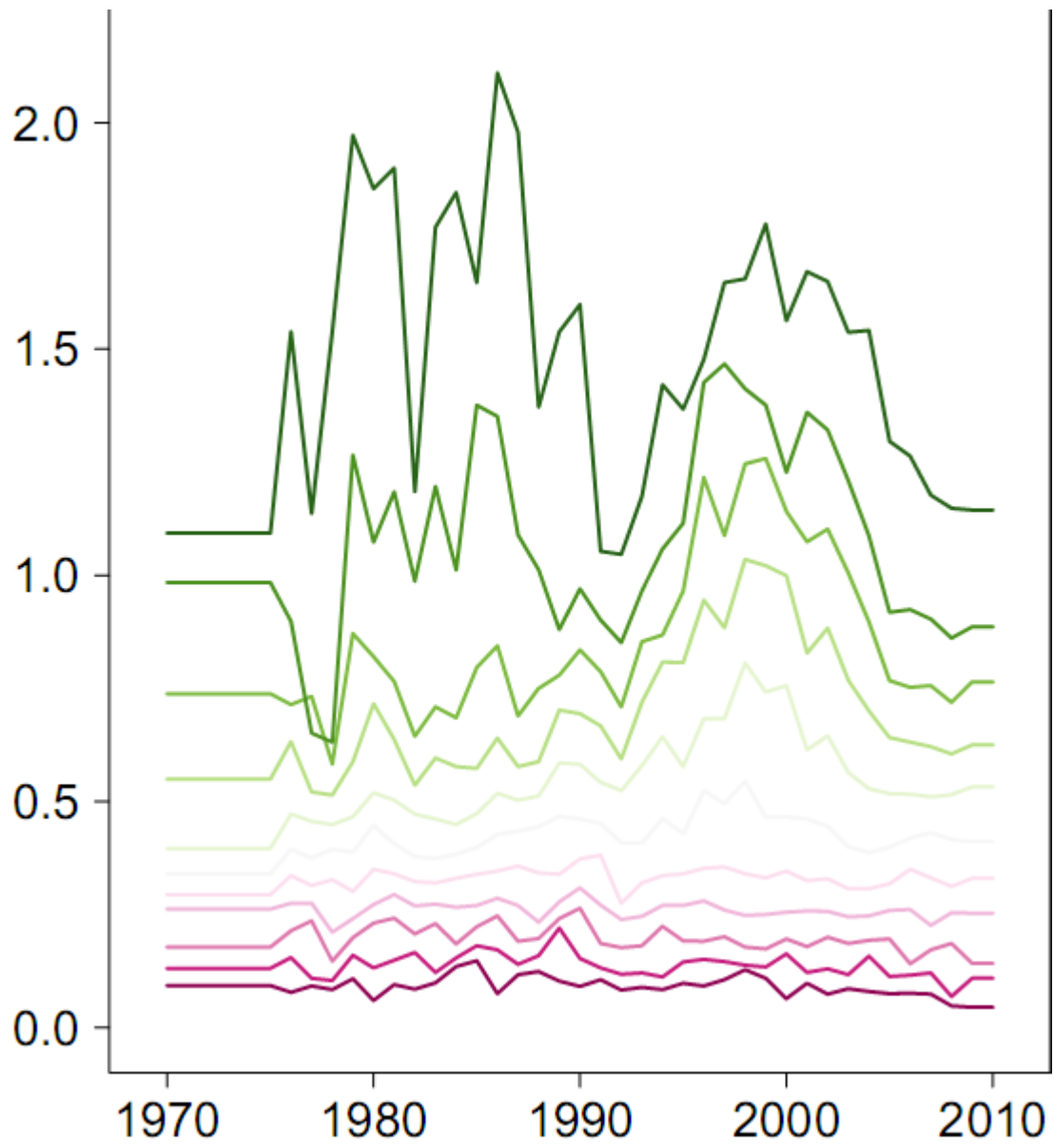


Figure 2. Mean weights-at-age over time used throughout the model.

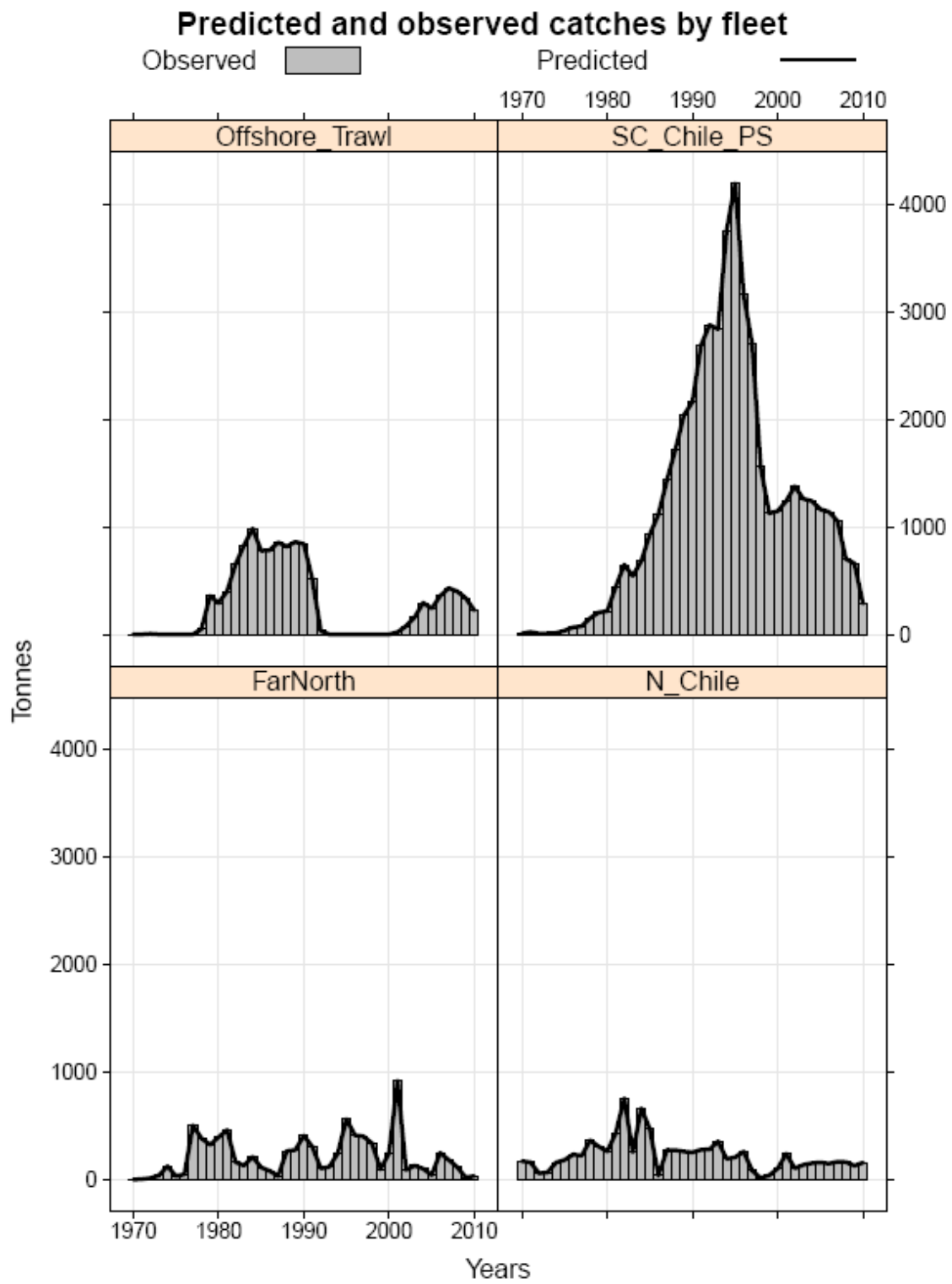


Figure 3. Model fit to the total catches by fleet. The bars represent the observations.

Residual catch at age by fleet

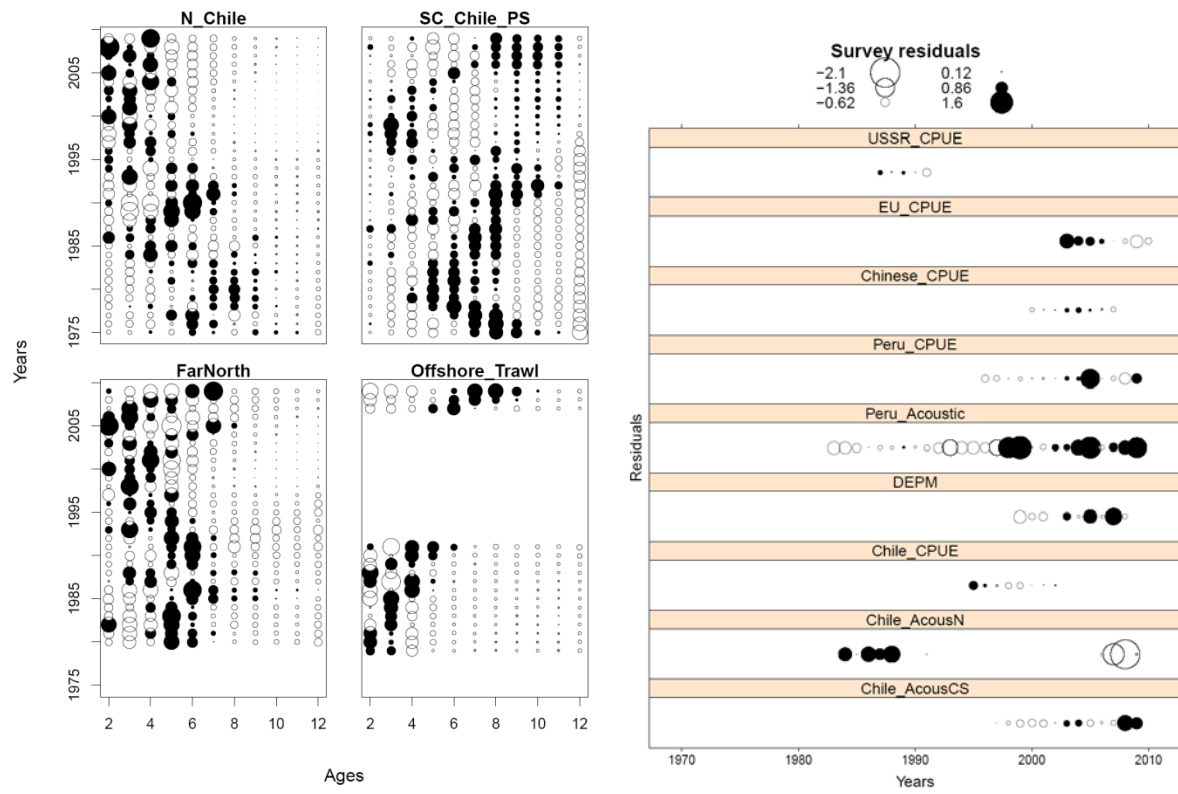


Figure 4. Logged residuals of observed and predicted catch-at-age proportions for the different fleets (left) and residuals for each of the indices (right).

Table 3. Years and type of information used on the stock assessment of jack mackerel.

Fishery	Catch at age	Catch at length	Landings	CPUE	Acoustic	DEPM
North Chile	1975-2009	-	1970-2010	-	1984-1988; 1991; 2006- 2009	1999-2008
South-central Chile	1975-2009	-	1970-2010	1995-2002	1997-2009	-
FarNorth (Peru)	-	1980-2009	1970-2010	1996-2009 China (2000- 2007); EU	1983-2009	-
Internacional	1979-1991	2007-2008	1978-2010	(2003-2010); exUSSR (1987-1991)	-	-

Table 4. Symbols definitions used for model equations

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: $i = \{1970, \dots, 2010\}$	i	
Age index: $j = \{2, 3, \dots, 12^+\}$	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
Virginal 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	$P_{ij}, \sum_{j=2}^{12} P_{ij} = 1.0$	$p_{ij}^f = \frac{\hat{C}_{ij}^f}{\sum_j \hat{C}_{ij}^f} \quad p_{ij}^s = \frac{N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}{\sum_j N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}$
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)		$j = 12+$	$N_{1970,12} = N_{1970,11} (1 - e^{-M})^{-1}$
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 $i = 1958, \dots, 2010$	$\varepsilon_i, \sum_{i=1958}^{2010} \varepsilon_i = 0$	$N_{i,2} = e^{\mu_R + \varepsilon_i}$
11)	Index catchability		$q_i^s = e^{\mu^s}$
	Mean effect	μ^s, μ^f	$s_j^s = e^{\eta_j^s} \quad j \leq \text{maxage}$
	Age effect	$\eta_j^s, \sum_{j=2}^{12+} \eta_j^s = 0$	$s_j^s = e^{\eta_{\text{maxage}}^s} \quad j > \text{maxage}$
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	$\eta_{ij}^f, \sum_{j=2}^{12+} \eta_{ij}^f = 0$	$s_{ij}^f = e^{\eta_{ij}^f}, j \leq \text{maxage}$ $s_{ij}^f = e^{\eta_{\text{maxage}}^f} \quad j > \text{maxage}$
	In years where selectivity is constant over time	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \neq \text{change year}$
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)	B_i	$B_i = \sum_{j=2}^{12} N_{ij} e^{-\frac{10.5}{12} Z_{ij}} W_{ij} P_j$
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 $B_0 = R_0 \varphi$ $\varphi = \sum_{j=2}^{12} e^{-M(j-1)} W_j P_j + \frac{e^{-12M} W_{12} P_{12}}{1 - e^{-M}}$

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	$L_2 = \sum_l \lambda_2^l \sum_{j=2}^{12^*} (\eta_{j+2}^l + \eta_j^l - 2\eta_{j+1}^l)^2$	Smoothness (second differencing), Note: $l=\{s, \text{ or } f\}$ 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	$L_5 = -\sum_{l,i,j} T_i^l P_{ij}^l \ln(\hat{P}_{ij}^l)$	$l=\{s, f\}$ 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	$L_6 = \lambda_6 \sum_{i=1977}^{2010} \ln \left(\frac{N_{i,2}}{\hat{R}_i} \right)^2$	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.

<i>L</i>	<i>s</i>	Abundance index	λ^s ⁽¹⁾	<i>L</i>	<i>f</i>	Catch biomass likelihood	λ^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	<i>s</i>	Smoothness for selectivities	λ^s ⁽¹⁾	5	<i>s</i>	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				
	<i>f</i>	Smoothness for selectivities	λ^f ⁽¹⁾	6	<i>f</i>	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	λ^s ⁽¹⁾			S-Recruitment curve fit	λ ⁽¹⁾
			1.4				1.4

(1) λ correspondsto $0.5/\sigma^2$:

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 Ex-USSR trawl fishery	Estimated from recent age composition data (post 1992) 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)	EU fleet CPUE	Assumed to be the same as 4)
13)	ex-USSR CPUE	Assumed to be the same as 4) but for earlier period

Table9. Growth parameters employed for convert the length compositions (Peru and ex-USRR) to age compositions.

Parameter	Peru (Unpublished)	Russia (Kochkin, 1994)	Chile (Gili et al, 1995)
L _∞ (cm)	68.8	74.2	70.8
k (year ⁻¹)	0.165	0.11	0.094
t ₀ (year)	-0.902	-0.89	-0.896

Table 10. Particular specifications for the different models applied.

Model	Description
Initial basecase	<ul style="list-style-type: none"> All indices assumed proportional to biomass
Model 1	<ul style="list-style-type: none"> Soviet age compositions from Russia 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 from Chile
Model 5	Downweight acoustic indices (Double CV)
Model 6	Downweight CPUE data (Double CV)
Model 7	Natural mortality alternative?

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

Index	n *	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 EU (**)	8	0.25 (2003-06)	0.25 (2003-06)	0.50 (2003-06)	0.25 (2003-6)
		0.20 (2007-10)	0.20 (2007-10)	0.40 (2007-10)	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:

in bold the changes

* number of observations

** between parenthesis the years

Table 12. Results of likelihood values by components for the 7 different 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
FisheryAge 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