INTER-AMERICAN TROPICAL TUNA COMMISSION
COMISIÓN INTERAMERICANA DEL ATÚN TROPICAL

WORKING GROUP TO REVIEW STOCK ASSESSMENTS

7TH MEETING

LA JOLLA, CALIFORNIA (USA)
15-19 MAY 2006

DOCUMENT SAR-7-07d

STATUS OF THE SWORDFISH STOCK IN THE SOUTHEASTERN PACIFIC OCEAN

Michael G. Hinton and Mark N. Maunder

1. EXECUTIVE SUMMARY

The southeastern Pacific Ocean stock of swordfish is distinctly identifiable by genetic and fisheries analyses.

Preliminary analyses of the status of the southeastern Pacific Ocean stock of swordfish indicates that the spawning biomass has declined significantly over the period from 1945 to 2003, and is now about twice the level which will support fisheries at average maximum sustained yield (AMSY = 13,000 to 14,000 t). Catches have increased substantially since 2001. Recent harvests are on the order of 14,000 – 15,000 t of swordfish annually.

2. DATA

The principal fisheries capturing swordfish in the eastern Pacific Ocean are discussed in detail in Hinton et al (2005). In the southeastern Pacific, the principal and most persistent of these are the fisheries of Chile (Barbieri et al, 1998; Yáñez et al, 2003) and Japan (Okamoto and Bayliff, 2003; Yokawa, 2005), which have taken a combined average annual catch of about 5,200 tons during the 1990s and about 5,500 tons since. The dominant fishery in most recent years is that of the European Union (Spain), which has taken on average about 5,700 t/yr since 2002 (Mejuto and García-Cortés, 2005).

2.1. Definitions of the fisheries

Seven fisheries are defined for the stock assessment of swordfish in the southeastern Pacific Ocean. These fisheries are defined based on the gear type, country, and/or spatial distribution. In general, the fisheries are defined so that, over time, there is little change in the age-specific selectivity of the fishery. The Japanese longline fishery was separated into a coastal and an offshore fishery (Figure 1). The model was run with two scenarios (A and B) for the JPN coastal fishery, based on the observation of increasing catch rates of smaller fish beginning in the late 1990s. Scenario B was conducted by further separating the JPN coastal fishery into early (pre-1999) and late (1999 and later) periods. Longline fisheries that are considered similar in style and area as the Japanese offshore area longline fishery were included therein. These included China, Chinese Taipei, Ecuador, French Polynesia, Korea, Uraguay, and Vanuatu.

The Spanish fleet changed from their traditional gear to American gear around 2001 which changed the characteristics of the fishery (Mejuto and García-Cortes, 2005). Therefore, the Spanish fishery is split into two time periods, early and late. The remaining fisheries, mainly from Chile were separated into artesanal fisheries, which catch larger fish using predominantly harpoon and gillnet gear, and an industrial longline fishery, which catches younger, smaller fish.

Fishery	Fishery name	Description
1	JPN coastal	Japanese longline in area 4 (east of 90°W) (pre-1999

		only for scenario B)
2	JPN offshore	Japanese longline in area 5 (west of 90°W)
3	SPN early	Spanish longline before 2001
4	SPN late	Spanish longline 2001 and later
5	Chilean artesanal	Artesanal fishery catch from Chile, Peru, and other costal nations
6	Chilean industrial	Chilean industrial longline
7 (scenario B only)	JPN coastal	Japanese longline in area 4, 1999 and later

2.2. Catch

Catch data in number of fish for the Japanese longline fisheries was provided by the National Research Institute of Far Seas Fisheries Japan (NRIFSF, Shimizu, Japan) for the period 1955 to 2003.

Catch for the Spanish fisheries were provided by the European Union (Instituto Español de Oceanografía, Coruña, Spain) in numbers of fish and in biomass (kg) for the 1991-2003 period. Description of the operations of the Spanish fishery, which began in the EPO in 1990, is well presented and updated by Mejuto and García-Cortes (2005). They note in this update a significant difference between catch rates of gear used in the early (Traditional gear) and later (American gear) periods of the fishery.

Catch data for the Chilean fisheries is described in TABLE 2.2.1c of Hinton et al, 2005. This catch series was augmented by adding data for Peru (Columns Smith and FAO, Appendix B2a. Weidner and Serrano 1997, p. 401), and it was extended to 1945 for Chile (Appendix E2a1, Weidner and Serrano 1997, p. 776). Total catch (t) by flag is shown in Table 1.

2.3. Indices of abundance

Several indices of abundance are available for the stock assessment of swordfish in the southeastern Pacific Ocean. All of these are based on catch-per-unit-of effort data.

Catch and effort data for Japanese fisheries were provided by the NRIFSF in numbers of fish and hooks fished by 5 degree area by month. Raw CPUE time series were generated for the JPN costal and JPN offshore fisheries. The CPUE series starts in 1952 for the JPN offshore fishery, but the geographical expansion of the Japanese fishery into the eastern Pacific Ocean did not reach area 4 until about 1967 (see Figure 1, Joseph et al, 1974).

Catch and effort for the Spanish fisheries were provided by the European Union (Instituto Español de Oceanografía, Coruña, Spain) in numbers of fish and in biomass (kg) by 5 degree area by month for the 1991-2003 period. Raw CPUE time series were generated for the early and late periods in the SPN fisheries.

Catch rates for Chile were obtained from Yáñaz et al (2003) [artesanal: 1987-1999; longline, 1994-1999] and Barría et al (2003) [longline: 2001-2002]. The artesanal and longline fisheries capture significantly different age distributions, as well as operating in different areas (Yáñaz et al 2003), and were modeled individually to account for differences in their selectivities.

2.4. Size and age composition

2.4.1. Size composition

Length-frequency data from Spanish fisheries was available in LJFL, and from Japanese fisheries in eye-fork length (EFL). LJFL was used in the stock assessment model. The EFL data was converted to LJFL using Uchiyama et al (1999). Length frequencies used in the model for the Japanese fisheries are shown in Figure 3.a, and for Spanish fisheries, in Figure 3.b.

2.4.2. Age composition

Age composition data was available from 1987 to 2001 for the combined artesanal and longline Chilean fishery, and as well data on length frequency was available for the period from 1994 to 2001 for the

Chilean artesanal fishery (Yáñez et al, 2003). The age frequency for the 1987-1997 period was reconstructed from the combined data by converting the length frequency data from the two fisheries into age frequency using a combined-sex age frequency distribution developed from the sex-specific growth models of Montiel (1996: cited by Barbieri 1998). The proportion at age by fishery was then used to separate the age-frequency data into the two fisheries. Age composition data for the industrial longline and the artesanal fishery were also available for the 1998-2001 period (Anonymous, 2005). Age frequencies used in the model for Chilean fisheries are shown in 3c.

3. ASSUMPTIONS AND PARAMETERS

3.1. Biological and demographic information

Detailed discussion and background information on biological parameters may be found in Hinton et al. (2005).

3.2. Growth

We used sex-specific growth models of Montiel (1996: cited by Barbieri et al, 1998), which were in terms of lower-jaw fork length (LJFL). The coefficient of variation of length at age in the model was assumed equal to 0.075. A common weight–length relationship was used.

3.3. Recruitment and reproduction

The age of first maturity for swordfish has been estimated as being between 4 – 6 yr: in this study, age of 50% maturity was set at about 5 yr. No a priori estimate of the stock-recruitment relationship was available for this stock, so a Beverton-Holt model with a steepness of 0.75 was assumed. The standard deviation of the log-normal distributional assumption for annual recruitment deviates was set at 0.6.

3.4. Movement

There is little information about movement of swordfish in the southeastern Pacific Ocean. However, genetic analysis (see stock structure) suggests that there is little or no exchange with the rest of the Pacific Ocean. No spatial structure was included in the population dynamics and therefore no movement parameters were built into the model.

3.5. Natural mortality

It has been estimated that swordfish natural mortality (M) is on the range of 0.2 – 0.5: in this study it was assumed 0.4.

3.6. Stock structure

Hinton et al (2005) reviewed the hypothesized stock structures of swordfish in the Pacific Ocean, placing an emphasis on the EPO. The IATTC has undertaken and supported collaborative investigations of stock structure of swordfish in the Pacific Ocean, also with particular emphasis on the EPO. Since a 2005 preliminary assessment of swordfish in the southeastern Pacific (Hinton and Maunder, 2005) , Alvarado et al (in press) have rejected hypotheses of mixed stocks in the Pacific, finding stong signals of distinct stocks of swordfish in the southeastern and northeastern Pacific Ocean by nDNA analysis, the latter region which was also distinguished from the Hawaiian-central Pacific area (Table 2).

4. STOCK ASSESSMENT

A stock assessment was carried out using Stock Synthesis II version 1.23b (SS2; Methot 2005). SS2 is an age-structured statistical stock assessment model programmed in AD Model Builder (http://otter-rsch.com/admodel.htm). SS2 is general, fits to multiple data types, and allows for a range of assumptions about the dynamics of the population and the fisheries. In general, for the swordfish application, the model is fit to multiple CPUE based indices of relative abundance, catch-at-length, and catch-at-age data.

In this study, the stock was considered at an equilibrium exploited population level in 1945, based on knowledge of existing fisheries (Weidner and Serrano 1997). The modeling timeframe began in 1945 and ended in 2003. The model was configured with 15 age-classes, with the oldest age-class acting as an accumulator for all fish 15 years of age and older.

Two scenarios were modeled for the stock assessment of swordfish in the southeastern Pacific Ocean. Scenario A had six fisheries: Japanese coastal longline, Japanese offshore longline, Spanish longline early period, Japanese longline late period, Chilean artesanal, and Chilean industrial longline. Scenario B was conducted by separating the Japanese costal fishery into early (pre-1999) and late (1999 and later) fisheries.

The catch for the Chile and Spanish fisheries, catch was available in weight. For most of the catch of the Japanese-like fisheries, catch was in numbers of fish. In the case of those States or catches for which only weights were available and included in the Japanese like fisheries, catch in numbers was estimated using annual estimates of average weight.

The age-specific selectivity for the Chilean artesanal fishery was constrained to be asymptotic, because this fishery catches the largest fish and does not appear to have a limit to size of captures. The other fisheries were allowed to have a dome-shaped age-specific selectivity (Figure 4) because even when fishing in regions near where large fish are know in catches, the catches regularly lack the largest individuals, and the modes of the age/length distributions are left-shifted (to younger fish). The modes of the selectivity curves were fixed based on initial runs of the model.

The approximate effective sample size for the length and age-frequency data likelihood were calculated from the estimated residuals from an initial run of the model. The abundance indices were all given the same value for the standard deviation of the likelihood function as there was no prior reason to support one over another.

4.1. Assessment results

The result from the SS2 model fitted to the CPUEs for swordfish fisheries are shown in Figure 5. In general, the model fits the CPUE data at about the level suggested by the assumed CV of 0.2. However, there is substantial autocorrelation in residuals. The poorest fits occur in the most recent time period for the Japanese fisheries and in the Chilean artesanal fishery. There is substantial conflict between the two Japanese longline fisheries in recent years. The CPUE index for the coastal fishery shows a substantial increase, while the offshore fishery has a steady decline. The model is unable to reconcile these conflicts in the data. The Chile artesanal fishery has shown a continuous decline in catch rates over the period 1987-1998, but the model was unable to predict the extent of the decline.

Gear selectivity for each of these fisheries is shown in Figure 5. There are substantial differences in age-specific selectivity among the fisheries. The Chilean artesanal fishery captures much older fish than the other fisheries. The Chilean industrial longline fishery also tends to capture older fish than the other longline fisheries. The late period Japanese coastal fishery appears to not catch the fish aged above 5 years that are caught in the earlier period or in the offshore fishery.

4.2. Recruitment

The current estimate of annual total recruitment, and a comparison to an estimate from the Hinton and Maunder (2005) assessment is shown in Figure 6.

Over the modeling timeframe, the stock has experienced a steep decline in recruitment during the early to mid-1950s, followed by a period of slowly increasing recruitment to the pre-1950 level which was reached in about 1971. Recruitment remained at about the average level (1,300) from around 1971 though 2000, when the index value increased to about 2,800 in 2001 and 4,200 in 2002, followed by a return to the normal recruitment level.

4.3. Biomass

The estimated vulnerable biomass from the model fit is shown in Figure 7. Though the estimated vulnerable biomass and the spawning biomass (Figure 8) have both cycled during the modeling timeframe, the spawning biomass has declined steadily since about 1980, in contrast to the vulnerable biomass, which risen since the mid-1990s. This is mainly due to the age at first vulnerability being less than the age at maturity. By 1961 the vulnerable biomass was already lowered due to low recruitments. The high recruitment seen at the end of the time series has kept vulnerable biomass high, but the high exploitation rates do not allow the cohorts entering the fishery to reach maturity, thus preventing them from entering the spawning population.

4.4. Residual plots

Bubble plots of residuals for model fits to the length and age data following fitting the SS2 model to the CPUE series are shown in Figures 9.a.1 – 9.a.3 for scenario A, and 9.b.1- 9.b.3 for scenario B.

4.5. Sensitivity to assumptions

No additional sensitivity analyses were conducted.

4.6. Comparison to previous assessments

The results are substantially different from those estimated last year. The overall decline in abundance over the modeling timeframe is less in the current assessment (Figure 10), and though the estimated trends in recruitment are similar through the mid-1970s, there are significant differences in more recent years (lower panel Figure 6). These differences result from the structural differences between the model and the inputs. In the 2005 assessment a single standardized CPUE series was used for the Japanese fishery The standardization model for 2005 included structure for area, gear, and other factors, but the structure of the SS2 model included only two fisheries (Japanese-like and Spanish-like) and it lacked area substructure. The current model included six (or seven) fisheries based on selectivities, including allowances for domed selectivities for fisheries which tend to not capture the largest individuals, and it incorporated spatial structure that is related to operation of fisheries and related in a general sense to the oceanographic features of the southeastern Pacific region off the coast of Chile and Peru. This area structure was a significant factor in the CPUE standardization model for Japanese longline catch rates for swordfish (Hinton et al 2005), which made it an important factor for inclusion in this model, as well. The evidence of difference is seen in the fits for Japanese Area 4 and Area 5 for 2005. The importance of including the information from the additional fisheries of Chile in this assessment can not be over stated. The additional information from the Chilean fisheries, including age structure data from the catch, made a significant impact on this assessment, adding the ability to separate the impact of the fisheries occurring on the entering recruits from those on the older fish contributing significantly to the spawning biomass. This added significantly to the ability of the model to resolve the overall status of the stock. The resulting differences may also be seen in the qualitatively similar trends of SBR, which declines over the modeling timeframe in both the current and the assessment of Hinton and Maunder (2005) (Figure 11).

4.7. Summary of the results from the assessment model

The population has experienced considerable changes in biomass and is currently at a moderate level of depletion. There is strong evidence of one or two large cohorts entering the fishery, however its strength is uncertain. Size and age-frequency data for 2004 and 2005 will improve the estimates of the size of these cohorts.

5. STOCK STATUS

5.1. Assessment of the stock based on spawning biomass

The trend in spawning biomass and in spawning biomass ratio (SBR: the ratio of the spawning biomass to that of the unfished stock, S_0) for the southern EPO swordfish stock are shown in Figure 7. SBR is estimated to have been between about 0.5 and 0.9 during the entire period of monitoring (1945-2003), having dipped as low as about 0.5 in the mid-1960s, and again in the mid-1990s. Under scenario A, SBR is currently estimated to be 0.67, and under Scenario B, 0.51. The SBR at AMSY is estimated to be about 0.26 under both scenarios.

5.2. Assessment of the stock based on AMSY

The average maximum sustained yield (AMSY) for the southern EPO swordfish stock is about 13,000 – 14,000 t under both scenarios, and the SBR at AMSY (S_{amsy}) is about 0.26. The current spawning biomass is at about 0.56 under Scenario A and 0.41 under Scenario B. Therefore, the stock is estimated to be well above the biomass the would support MSY.

The average annual catch from the this stock during the 1993 – 2000 period was about 6,900 t (range ~ 4,800 – 8,600 t). Catches in recent years have been on the order of 12,000 – 13,000 t, which are about the estimated AMSY catch level. In addition, there have been indications of increasing efficiency and targeting of swordfish in the southern EPO, which has resulted in increased harvests of this stock. It is also noted also that some of the increased catch may have resulted from the high recruitments noted previously. It is not expected that further increases in the high catch levels observed in recent years would be sustainable.

No calculations have been made to determine the level of AMSY that could be obtained by each fishery operating exclusively. However, it is likely that the fisheries that capture younger fish (e.g. the longline fisheries of Chile, Japan and Spain) are less efficient at maximizing yield. There is potential for growth-over fishing analogous to that of longliners and purse seiners fishing for bigeye tuna in the eastern Pacific Ocean (Maunder and Hoyle, 2005), with the Chilean artesanal fishery in the role of longliner and the Chilean/Japanese/Spanish longliners, which capture the younger fish, in the role of purse seiner.

5.3. Summary of the stock status

The stock biomass is above the level that would support AMSY. The current catch levels are estimated to be about the AMSY level. However, there have been recent increases in the longline fisheries which are harvesting the younger age classes of swordfish, which may result in fewer numbers of individuals entering the spawning biomass. The model shows a continuing decrease in spawning biomass, and if this trend continues it suggests that it will be at some point necessary to recommend restriction of fishing activities for one or more components of the current fishing fleets. There is also the potential for yield-overfishing due to the small average size of the fish caught.

6. FUTURE DIRECTION

It is recommended that yield-per-recruit type analysis be conducted to more fully explore the status of swordfish stock..

It is recommended that complete information on fisheries (e.g. catch, effort, age and length-frequency data) be obtained from all parties to the IATTC for incorporation in modeling work.

It is recommended that comprehensive CPUE standardization be carried out for all CPUE times series used in the assessment model.

It was recognized during this assessment that access to information from Chile is problematic, and it is recommended that such information be sought through all identifiable means.

It is recommended that fisheries in the region be closely monitored for changes, and given the increase in targeting fisheries for swordfish and the decreasing trend in spawning biomass, that the status of the stock be updated in 2007,

LITERATURE CITED

Alvarado Bremer, J. R., M. G. Hinton, and T. W. Greig. (In Press). Evidence of spatial genetic heterogeneity in Pacific swordfish (*Xiphias gladius* L.) revealed by the analysis of ldh-A sequences. Bull. Mar. Sci., 22 p.

Anonymous. 2005. II Taller tecnico-cientifico sobre el pez espada en el pacifico sudeste. Comisión Permanente del Pacífico Sur. Valparaíso, May 16-17, 2005. 88 p.(www.cpps-int.org/spanish/cientifico/informe%20Taller%20Pez%20espada%20v%20final.pdf)

Barbieri, M.A., C. Canales, V. Correa, M. Donoso, A.G. Casanga, B. Leiva, A. Montiel, and E. Yáñez. 1998. Development and present state of the swordfish, *Xiphias gladius*, fishery in Chile. NOAA Technical Report NMFS 142, 1:10.

Barría M., P., M. Donoso P., and J. Acededo V. 2003 Pesquería pez espada: Investigación situación pesquería recursos altamente migratorios, 2002. Informe de difusión, Instituto de Fomento Pesquero, Chile. 11 p.

(www.ifop.cl/doc_enlinea/Migratorios2002.pdf)

Hinton, M. G. 2003. Status of swordfish stocks in the eastern Pacific Ocean estimated using data from Japanese tuna longline fisheries. Mar. Freshwat. Res. 54: 393-399.

Hinton, M. G., and M. N. Maunder. 2005. Status of the swordfish stock in the southeastern Pacific Ocean. Report to the Multilateral Consultation of Swordfish in the South-East Pacific Ocean. June, 2005, Lanzarote, Spain. 10 p.

Hinton, M. G., W. H. Bayliff, and J. Suter. 2005. Assessment of swordfish in the eastern Pacific Ocean. Inter-Amer. Trop. Tuna Comm. Stock Assess. Rpt. 5, 291:326.

Joseph, J., W. L. Klawe, and C. J. Orange. 1974. A review of the longline fishery for billfishes in the eastern Pacific Ocean. In: Shomura, R. S., and F. Williams (Ed.). NOAA Tech. Rpt NMFS/SSRF-675, 309-331.

Maunder, M. N., and S. D. Hoyle. 2005. Status of bigeye tuna in the eastern pacific ocean in 2004 and outlook for 2005. IATTC Stock Assess. Rpt. 5, 168-290.

Mejuto, J., and B. García-Cortés. 2005. Update of scientific and technical information on the activitity of the EU-Spanish surface longline fleet targeting the swordfish (*Xiphias gladius*) in the Pacific, with special reference to recent years: 2002 and 2003. Manuscript. Doc BSTC 2005, Lanzarote (Spain), Jun 26-27, 2005. 17 p.

Methot, R. 2005. Pers. Comm. Technical Description of the Stock Synthesis II Assessment Program.

Montiel, A. 1996. Determinación de la edad y del crecimiento del pez espada (*Xiphias gladius*) explotado frent a las costas de Chile. Thesis, Univ Católica de Val Paraíso, Chile, 79 p.

Okamoto, H., and W. H. Bayliff. 2003. A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1993-1997. Inter-Amer. Trop. Tuna Comm. Bull. 22(4): 219-431.

Uchiyama, J. H., E. E. DeMartini, and H. A. Williams. 1999. Length-weight interrelationships for swordfish, Xiphias gladius L., caught in the central north Pacific. NOAA-TM-NMFS-SWFSC-284, 82 p.

Weidner, D.M., and J.A. Serrano. 1997. World Swordfish Fisheries. NOAA Tech. Memo. NMFS-F/SPO-26 Vol. IV., 843 p.

Yáñez R., E., M. A. Barbieri B., F. Ponce M., M. Donoso P., C. Canales R., R. Toro N., and J. Acevedo V.. 2003. Monitoreo y evaluación de la pesquería Chilena de pez espada. Actividad Pesquera y de Acuicultura en Chile. Escuela de Ciencias del Mar, Facultad de Recursos Naturales, Pontificia Universidad Católica de Valparaíso, 143-156.

Yokawa, K. 2005. Swordfish catch of Japanese distant-water longliners in the eastern Pacific. Report to the Multilateral Consultation of Swordfish in the South-East Pacific Ocean. June, 2005, Lanzarote, Spain. 8 p.

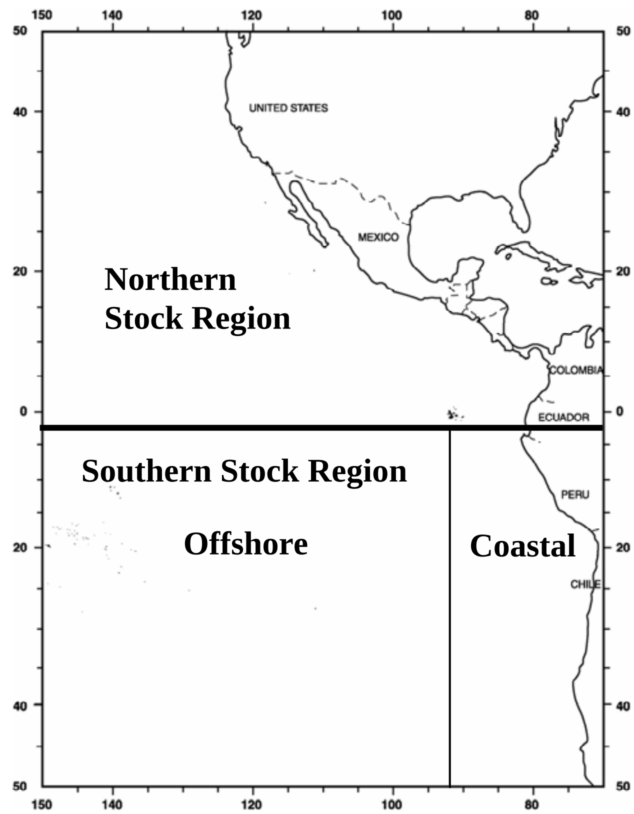


FIGURE 1. Subareas "Offshore" and "Coastal" of the EPO southern stock area (south of 5ºS) in the SS2 model.

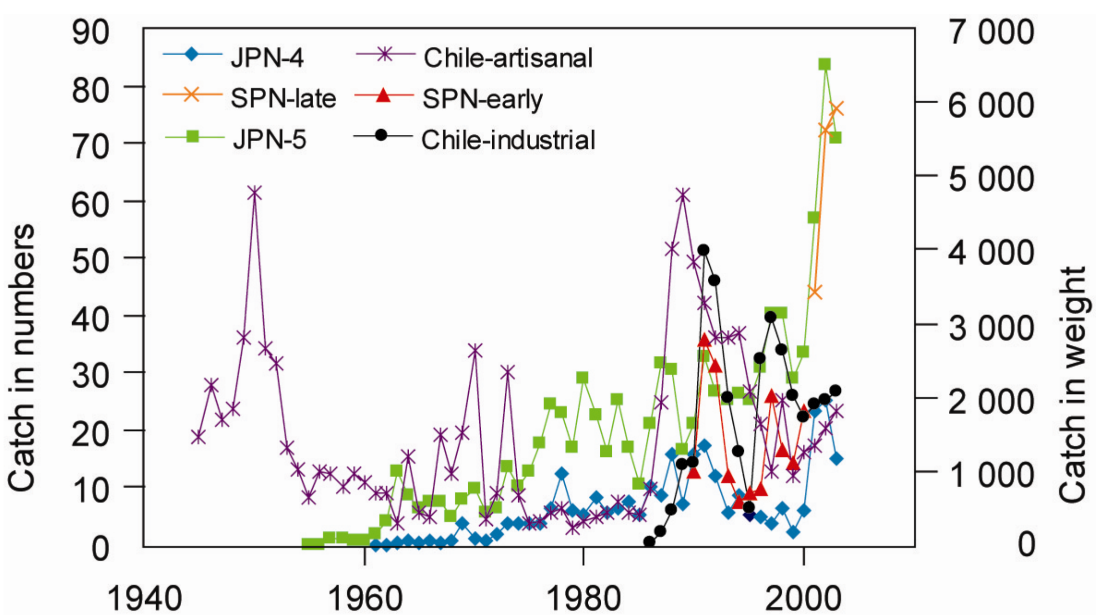
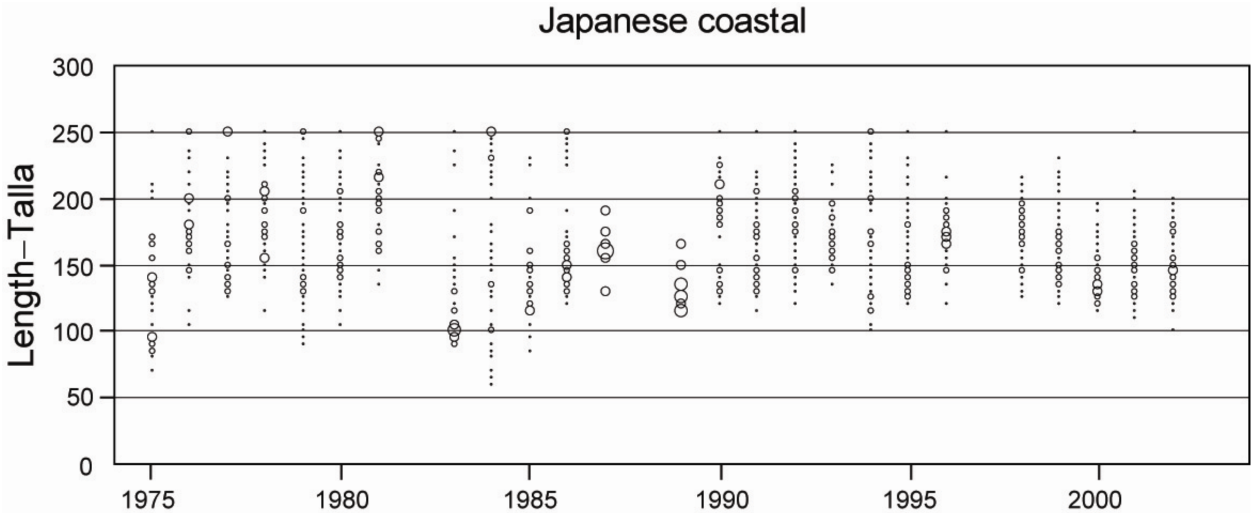


FIGURE 2. Catch by fishery in weight (t) and numbers of fish in the southeast swordfish SS2 model inputs.



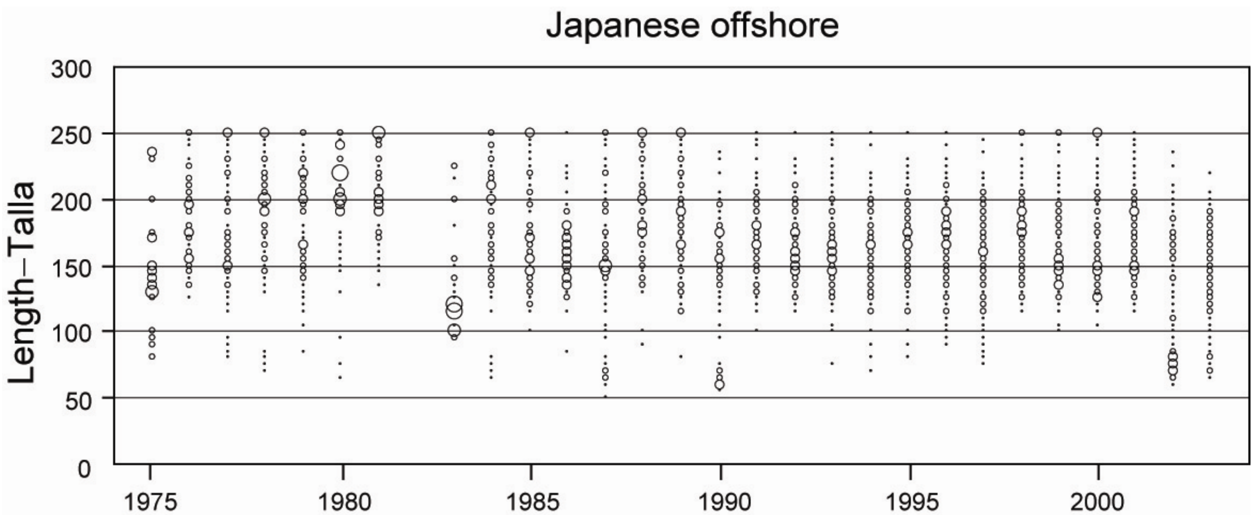


FIGURE 3.a. Length frequency (lower-jaw fork length) distributions of swordfish from the southern EPO from Japanese coastal and offshore fisheries

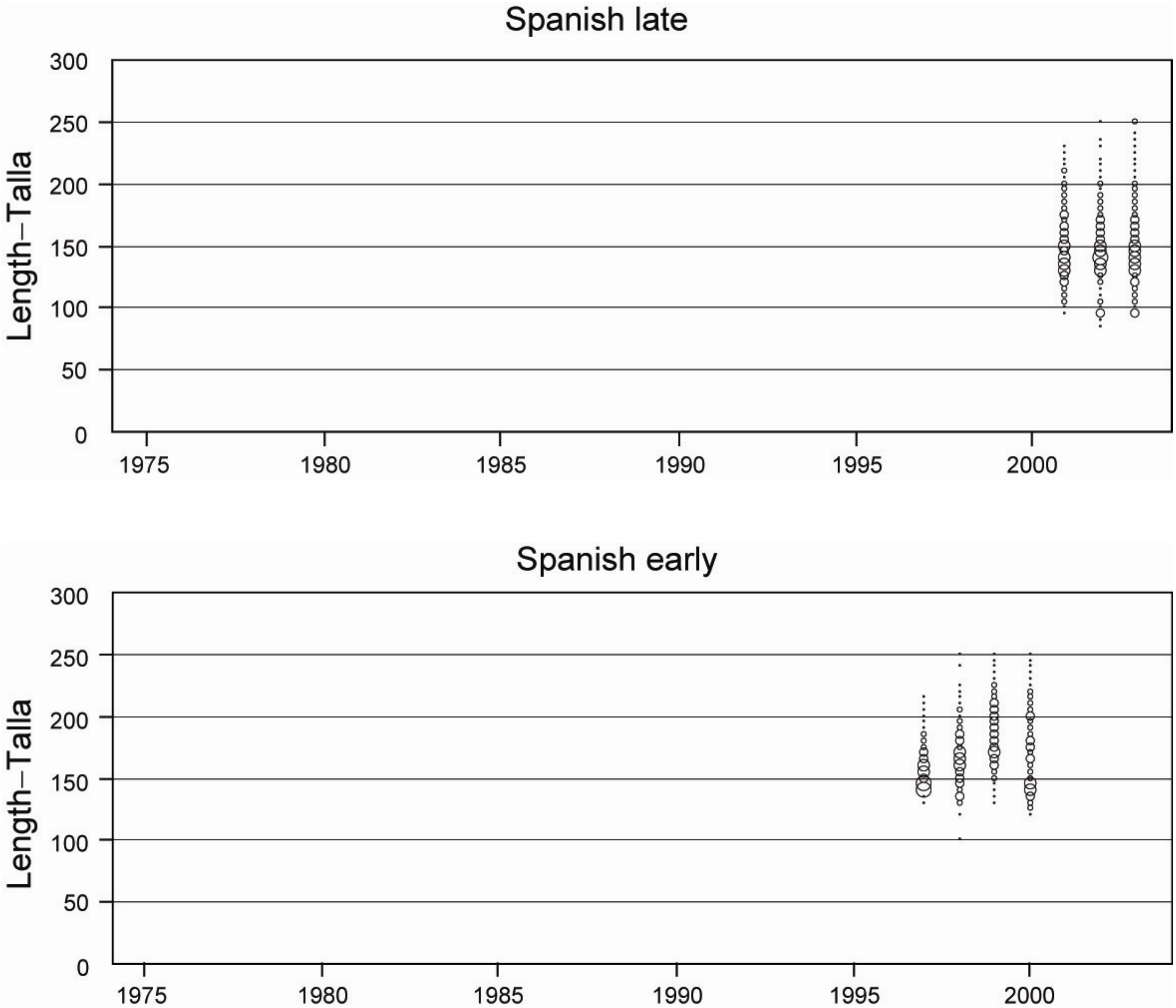
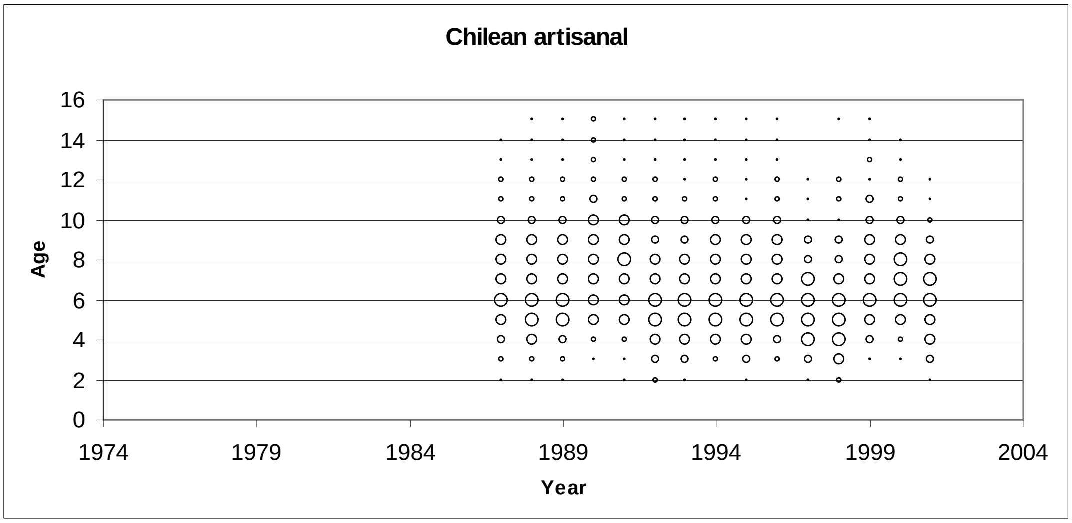


FIGURE 3.b. Length frequency (lower-jaw fork length) distributions of swordfish from the southern EPO from Spanish early and late period fisheries.



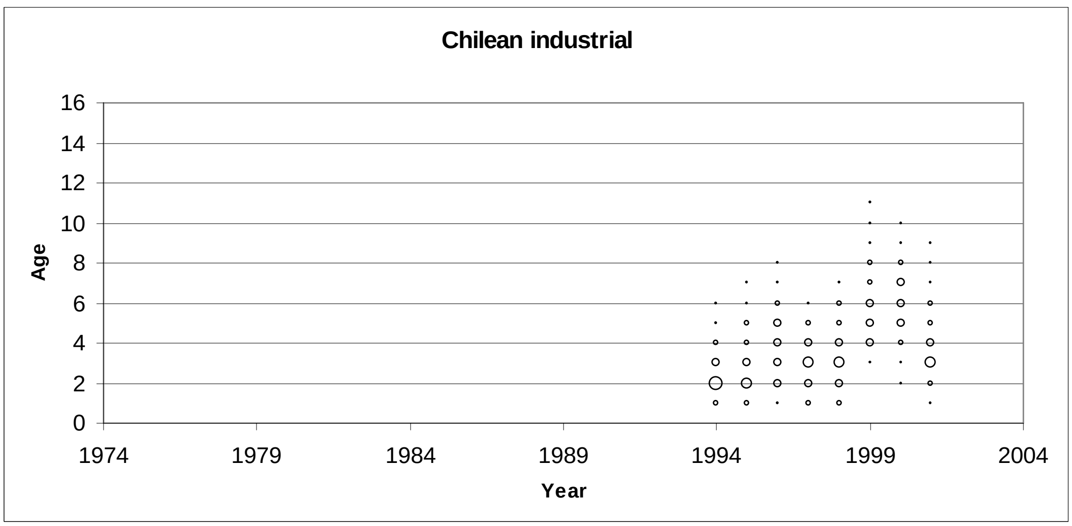


FIGURE 3.c. Age frequency distributions of swordfish from the southern EPO from Chilean artesanal and industrial longline fisheries.

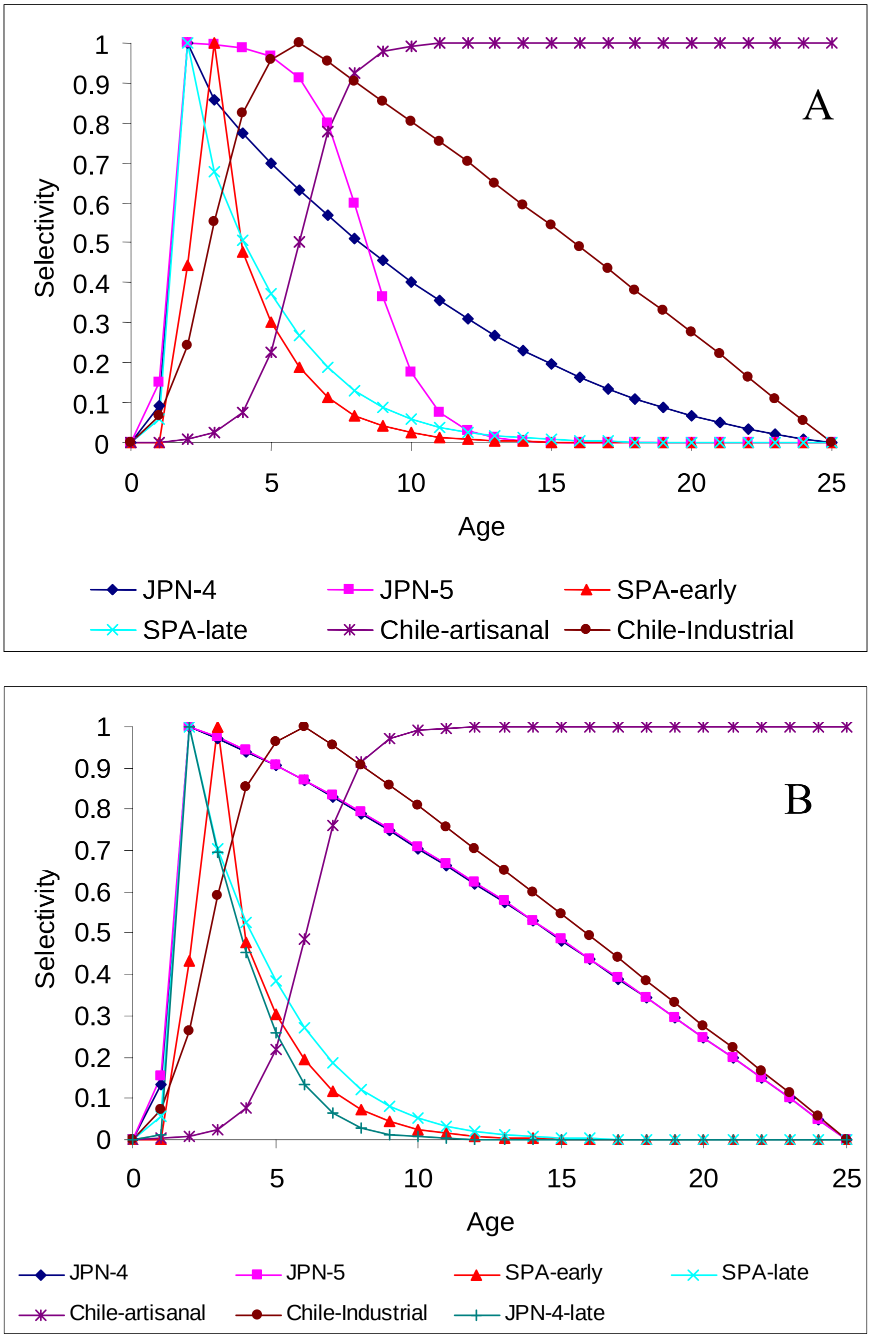


FIGURE 4. Selectivity for fisheries included in the SS2 model for swordfish in the southwest Pacific Ocean for scenarios A and B.

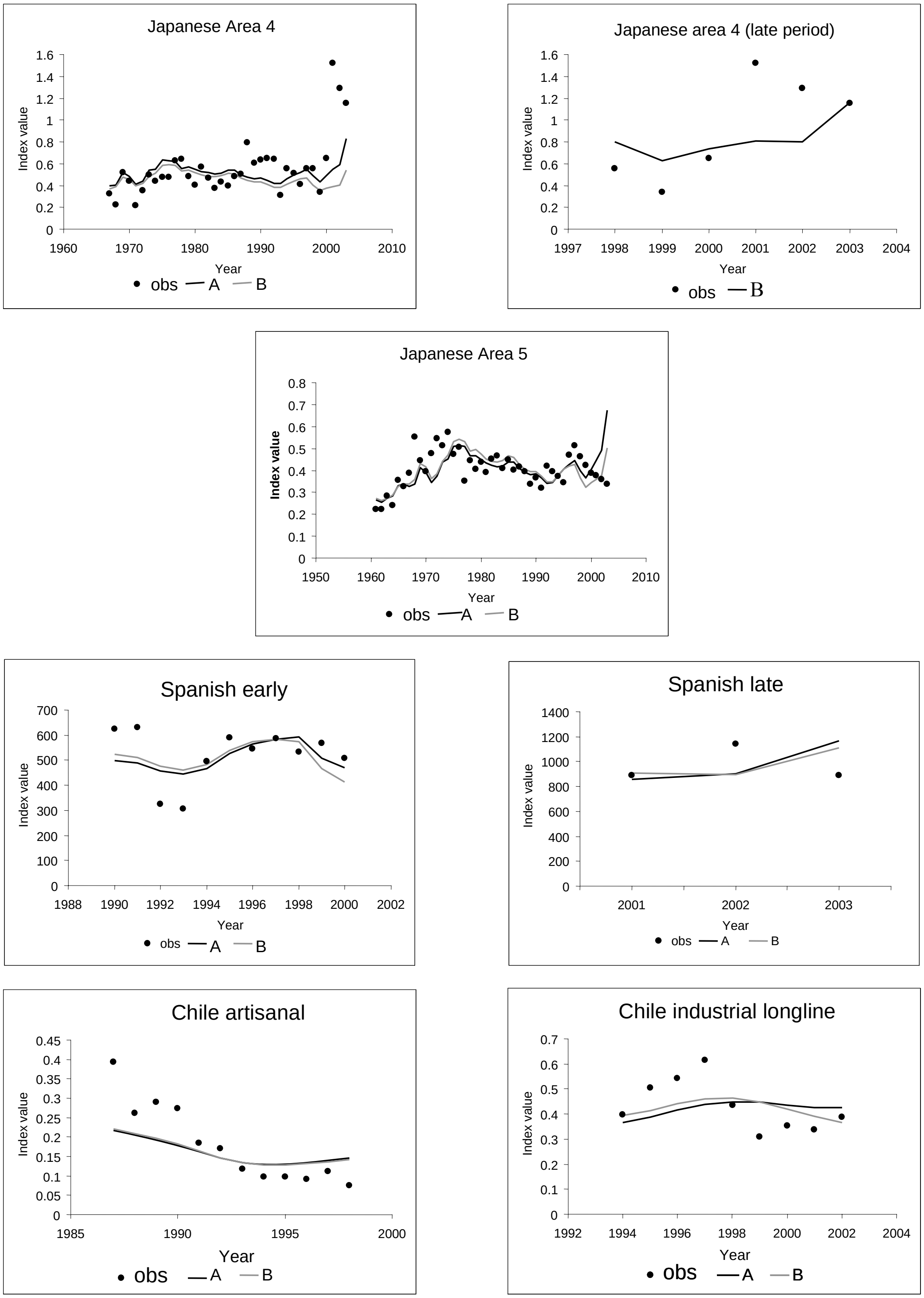


FIGURE 5. Observed catch rates and fitted indices for fisheries included in SS2 model of swordfish in the southeast Pacific Ocean for scenarios A and B.

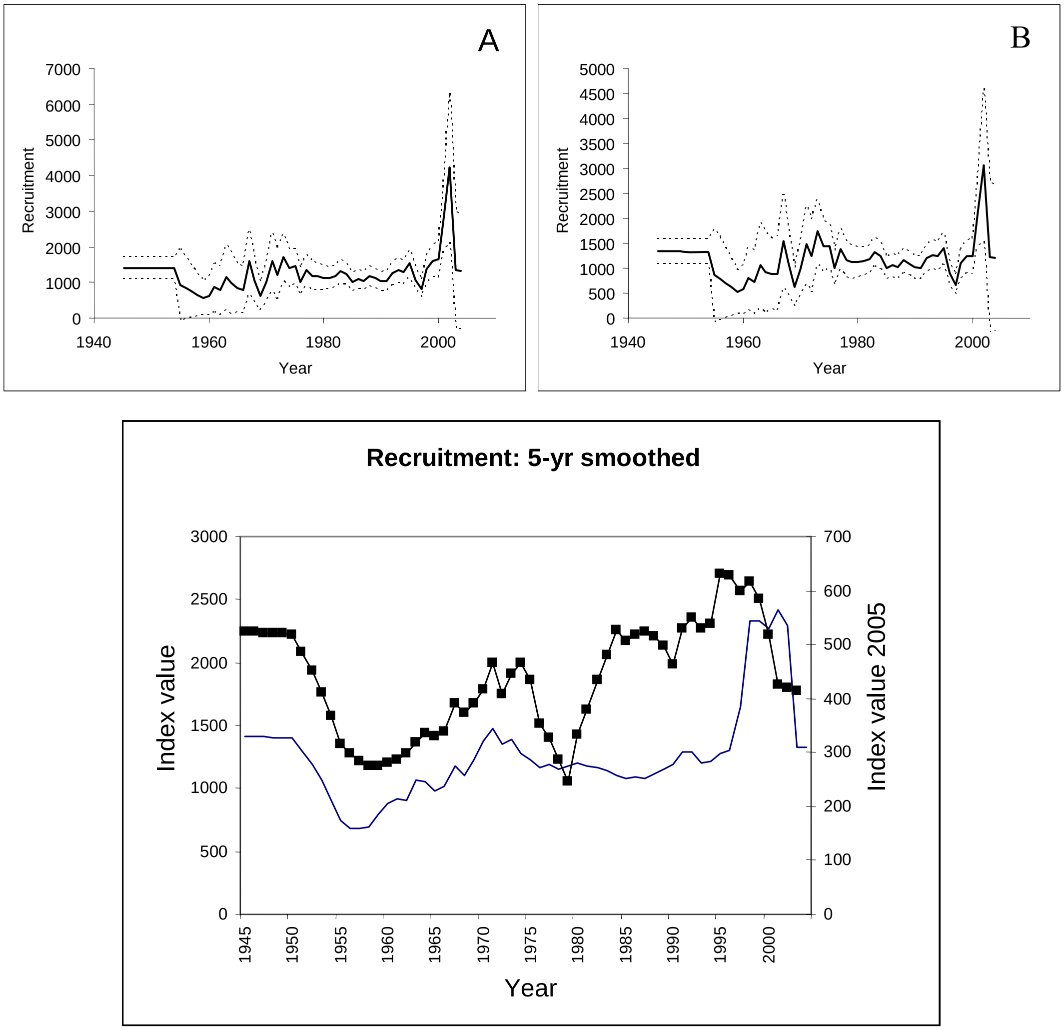


FIGURE 6. Estimated annual recruitment under scenarios A and B, and comparison of smoothed recruitment indices from the current scenario A and the Hinton and Maunder (2005, dotted line) SS2 model outputs.

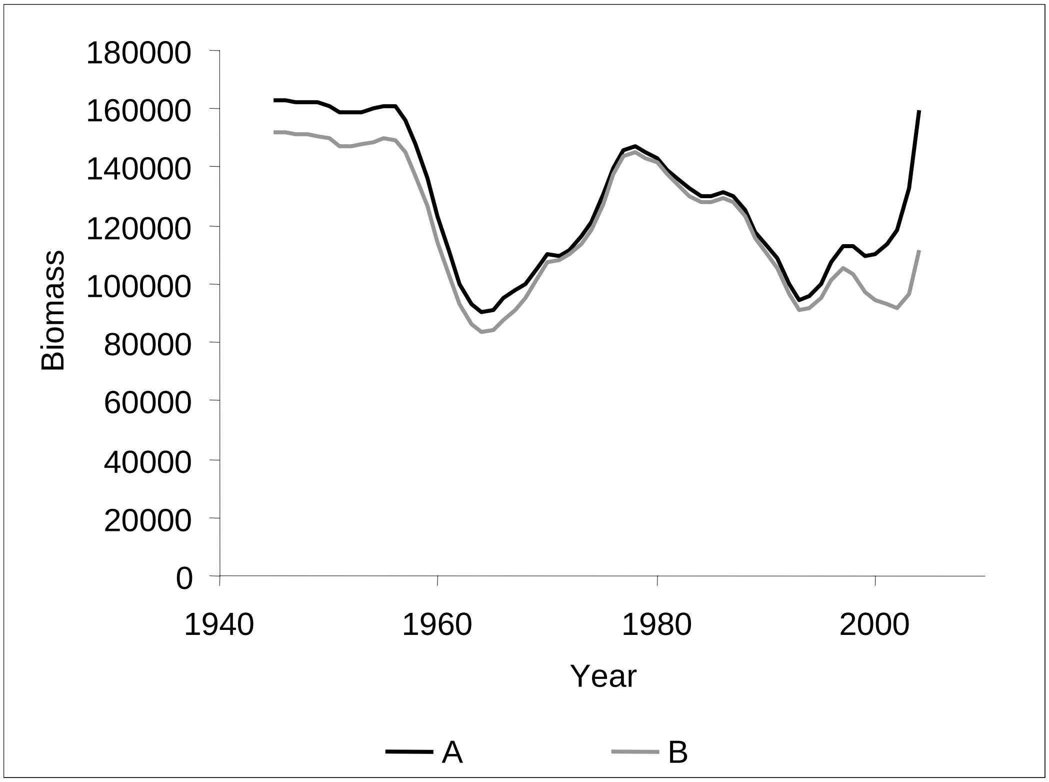


FIGURE 7. Estimated trend in vulnerable biomass (t) of swordfish in the southeast Pacific from SS2 model for two scenarios (A and B)

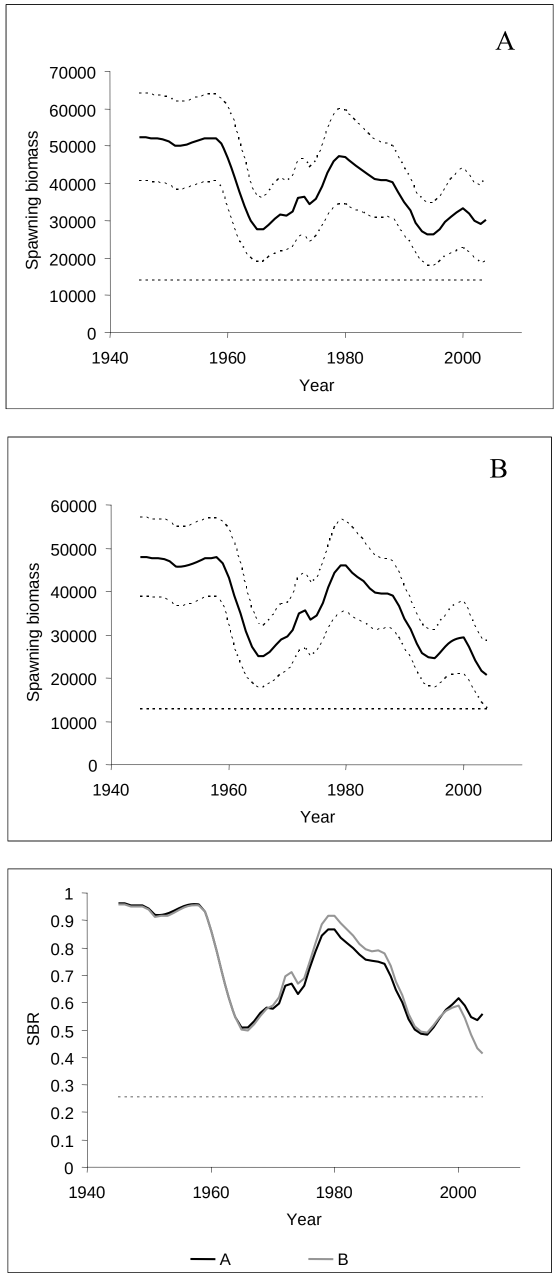
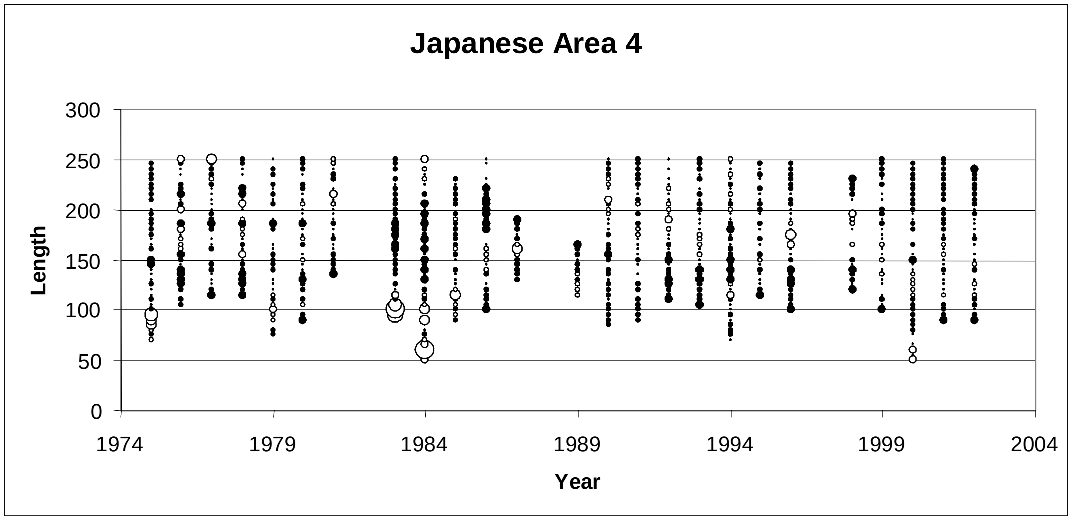


FIGURE 8. Trends in spawning biomass with 95% C.I. (scenarios A and B, upper panel) and spawning biomass ratio (SBR, lower panel) for swordfish in the south EPO.



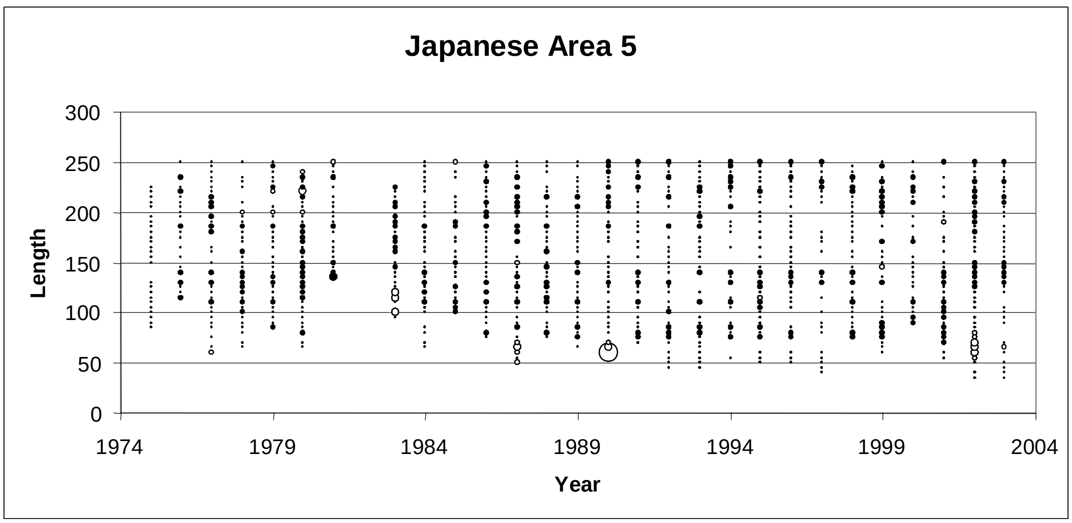
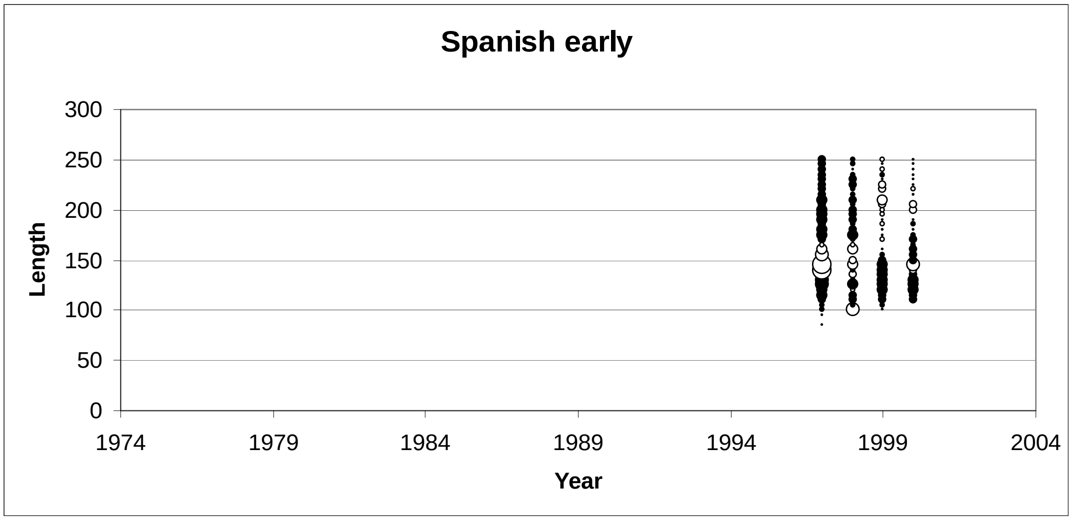


FIGURE 9.a.1. Residuals of the fit to the age and length-frequency data for Japanese fisheries scenario A.



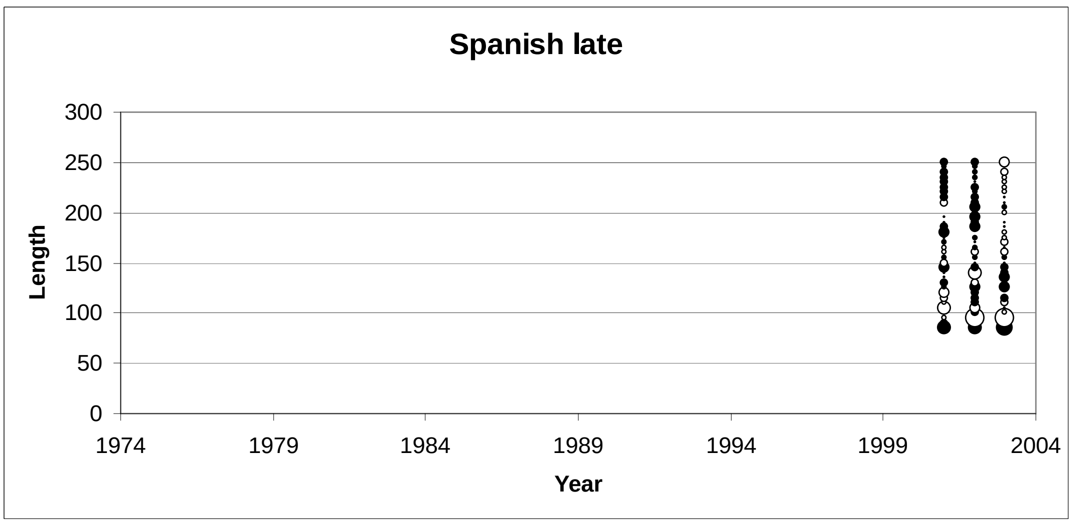
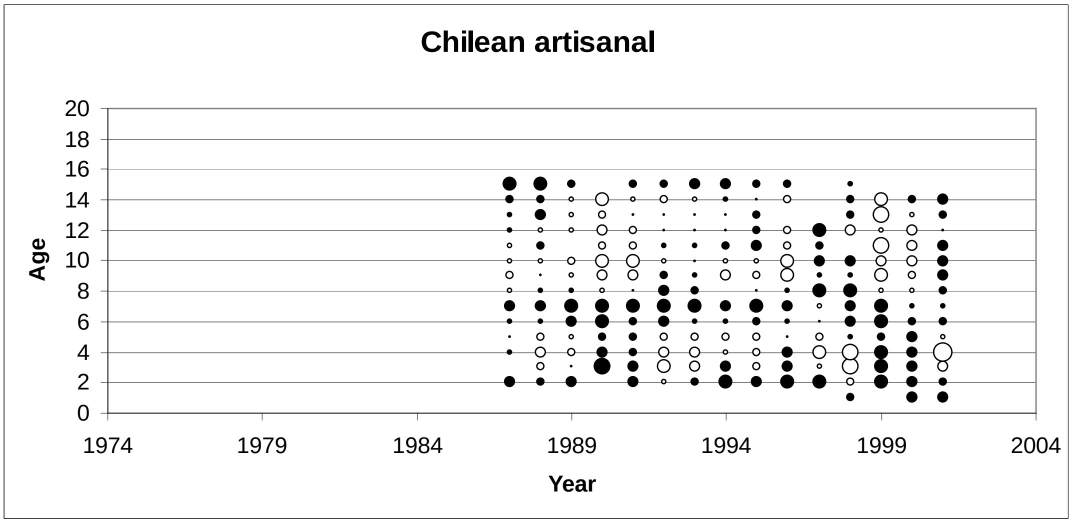


FIGURE 9.a.2. Residuals of the fit to the age and length-frequency data for Spanish fisheries scenario A.



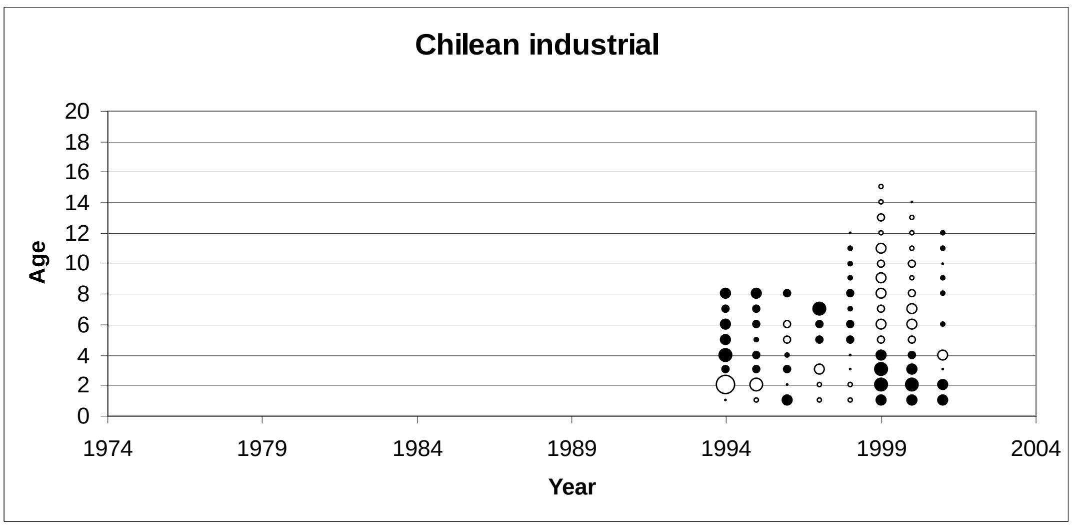


FIGURE 9.a.3. Residuals of the fit to the age and length-frequency data for Chilean fisheries scenario A.

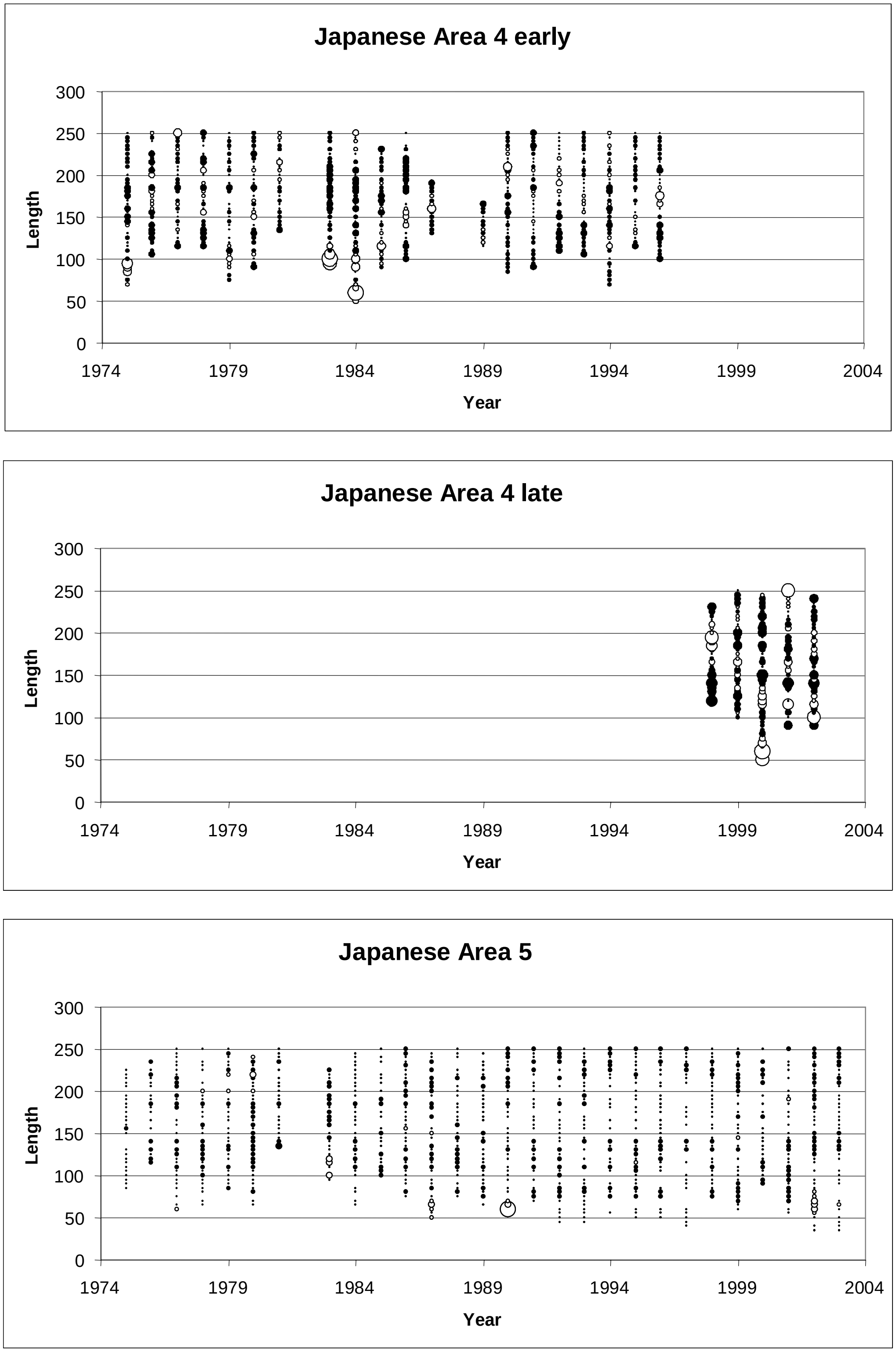
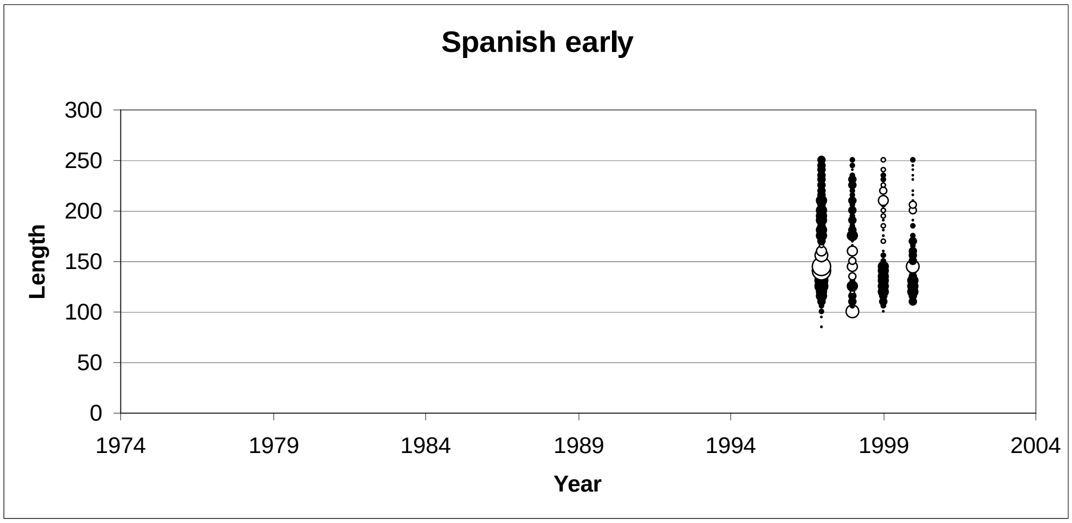


FIGURE 9.b.1. Residuals of the fit to the age and length-frequency data for Japanese fisheries in scenario B.



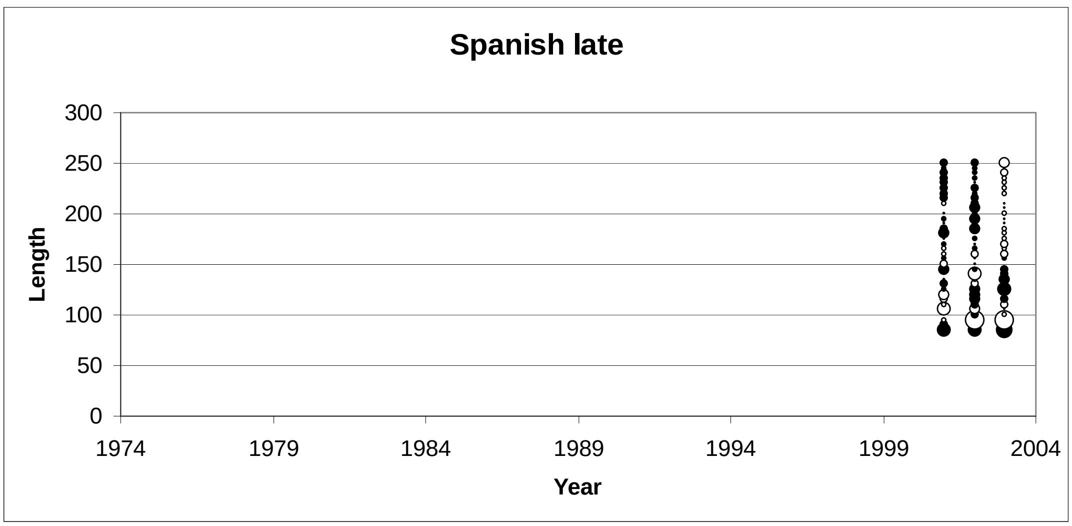
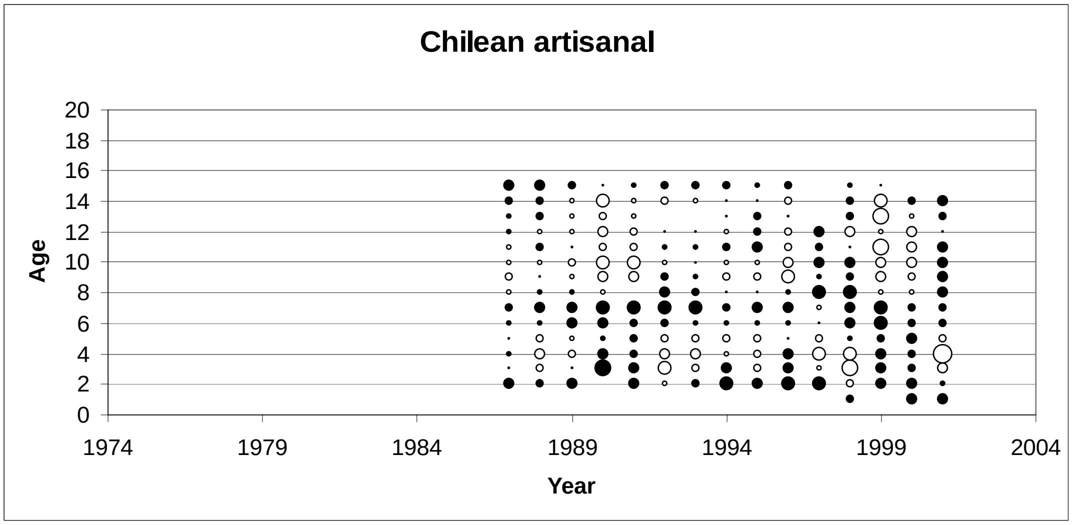


FIGURE 9.b.2. Residuals of the fit to the age and length-frequency data for Spanish fisheries in scenario B.



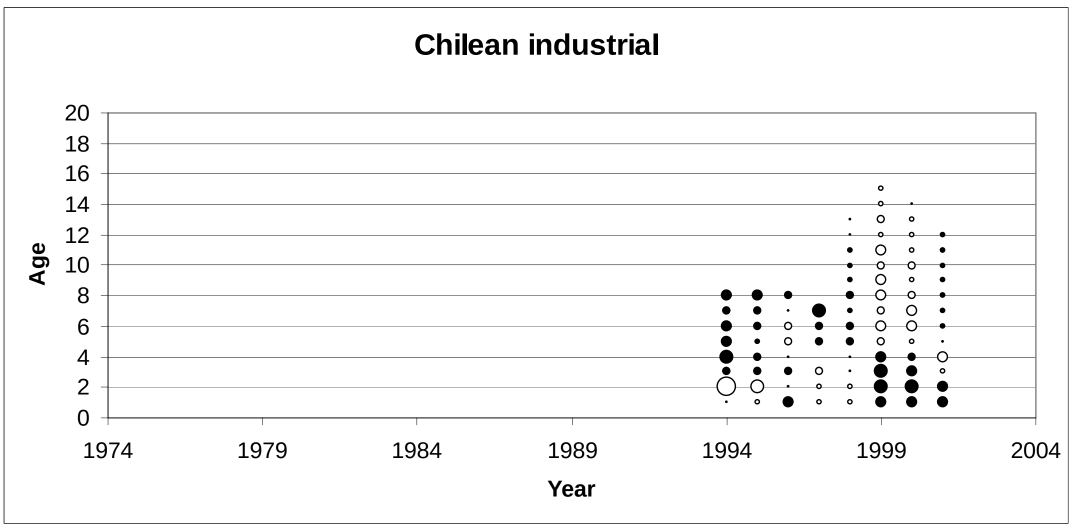


FIGURE 9.b.3. Residuals of the fit to the age and length-frequency data for Chilean fisheries in scenario B.

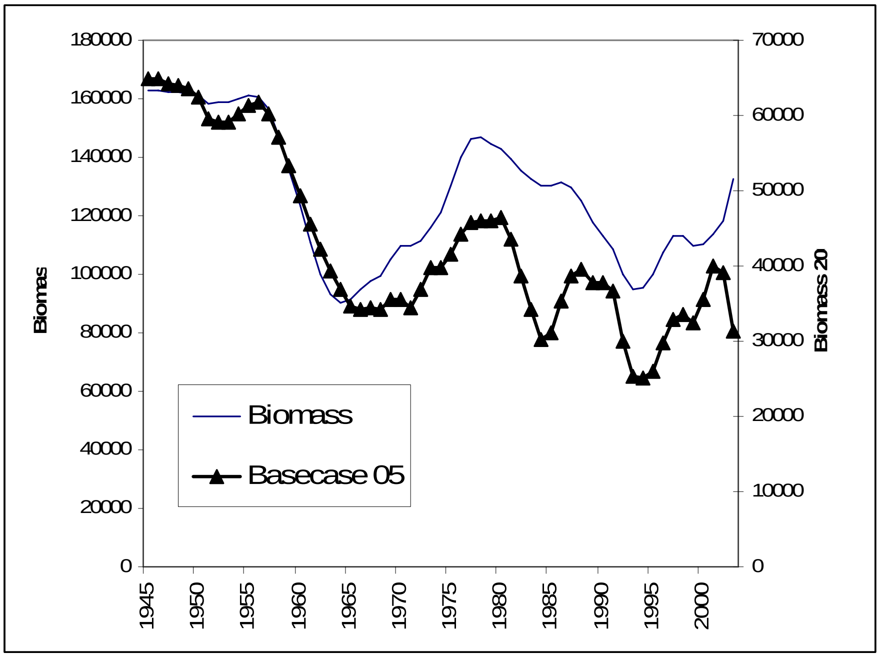


FIGURE 10. Comparison of trends in biomass in the current assessment to that of Hinton and Maunder (2005, Base case 05).

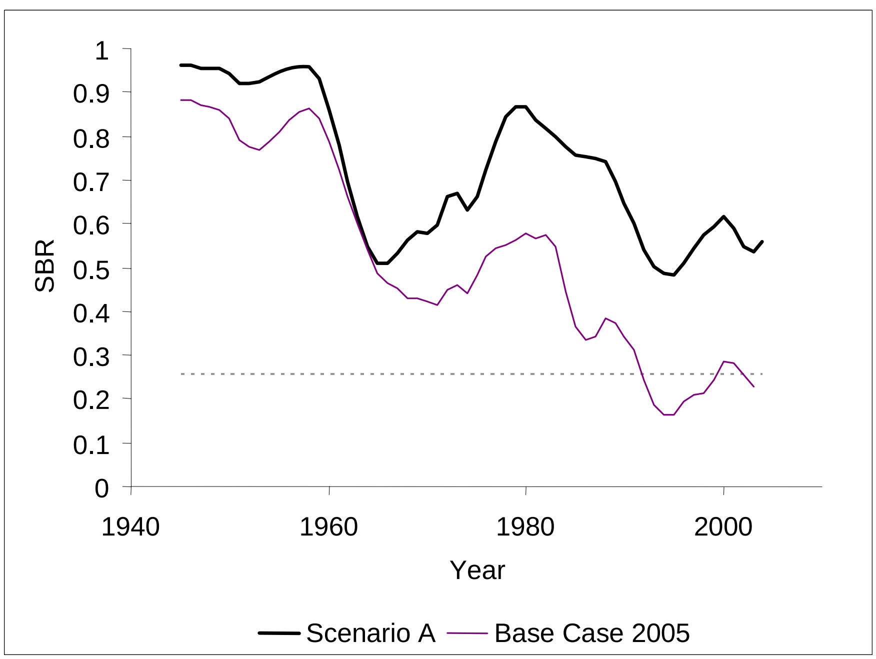


FIGURE 11. Comparison of trends in spawning biomass ratio (SBR) from SS2 model fits of current assessment scenario A to that of Hinton and Maunder (2005, Base case 2005).

TABLE 1. Catches of swordfish, in metric tons, in the eastern Pacific Ocean south of 5°S.
TABLA 1. Capturas de pez espada, en toneladas métricas, en el Océano Pacífico oriental a sur de 5°S.

Year	CHL	CHN	COL	CRI	ECU	ESP	JPN	KOR	PAN	PER	PYF	TWN	OTR	Total
1945	1,455													1,455
1946	2,166													2,166
1947	1,701													1,701
1948	1,209													1,209
1949	690													690
1950	786									6,900				7,686
1951	870									2,400				3,270
1952	570									1,900				2,470
1953	416									900				1,316
1954	334									700				1,034
1955	237						1			400				638
1956	386						4			600				990
1957	357						54			600				1,011
1958	392						64			400				856
1959	555						32			400				987
1960	456						36			400				892
1961	394						104			300				798
1962	297						211			400				908
1963	94						676			200				970
1964	312						471			900		0		1,684
1965	151						344			300		0		795
1966	175						402			200		0		777
1967	203						390			1,300		31		1,924
1968	175						261			800		17		1,253
1969	314						570			1,200		6		2,090
1970	243						542			2,396		26		3,206
1971	181						261			185		18		645
1972	141						368			550		38		1,097
1973	410						912			1,941		30		3,293
1974	218						694			470		34		1,416
1975	137						882	3		158		9		1,189
1976	13						1,210	15		295		34		1,567
1977	32						1,654	16		420		31		2,154
1978	56						2,045	29		436		8		2,574
1979	40						1,226	13		188		30		1,497
1980	104						2,103	32		216		17		2,472
1981	294						1,653	79		91		33		2,150
1982	285						1,144	26		154		31		1,640
1983	342						1,771	28		238		9		2,388
1984	103						1,538	37		343		15		2,036
1985	342						868	70		55		12		1,347
1986	764						1,473	60		21		12		2,330
1987	2,059						1,661	144		73		28		3,965
1988	4,455						2,233	110		54		38		6,891
1989	5,824						1,216	43		3		74		7,160
1990	4,955					1,007	1,596	170		1		24		7,753
1991	7,255		29	107		2,794	1,896	402		3		28		12,515

Year	CHL	CHN	COL	CRI	ECU	ESP	JPN	KOR	PAN	PER	PYF	TWN	OTR	Total
1992	6,379			27		2,435	2,020	172		16	2	27		11,079
1993	4,712			20		928	1,505	159		76	2	19		7,421
1994	3,801			27		575	1,627	121		310	16	44		6,523
1995	2,594			29		698	1,213	290		7	25	6		4,861
1996	3,145			315		772	1,186	332		1,013	25	12		6,800
1997	4,040			1,072		2,018	1,169	250		24	23	37		8,634
1998	4,492		6	419		1,293	2,004	357		98	20	78		8,767
1999	2,925			99	56	1,118	1,257	401		15	30	84		5,985
2000	2,973			407	103	1,807	1,184	353	2	2	46	110	1	6,988
2001	3,262	111		653	29	3,427	2,436	350	432		47	462	1	11,210
2002	3,523	321		638	37	5,629	2,367	325	433	14	4	2,080	43	15,415
2003	3,848	816		286		5,913	2,306	161	287	26	87	1,396	355	15,481
2004	3,268	236		179		5,607	1,919			1,056	63		3	12,332

CHL, Chile; CHN, China; COL, Colombia; CRI, Costa Rica; ECU, Ecuador; ESP, España—Spain; JPN, Japan—Japón; KOR, Republic of Korea—República de Corea; MEX, México, PAN, Panamá; PER, Perú; PYF, French Polynesia—Polinesia Francesa TWN, Chinese Taipei—Taipei Chino;

TABLE 2. Regional genetic differentiation among pooled samples of Pacific swordfish. Pair-wise FST values between regions (above diagonal). P-values (S.E.) of genic differentiation for each population pair (below diagonal). Significant values after sequential Bonferroni corrections for multiple tests (initial ∩ = 0.05/6 = 0.008) are indicated in boldface. (From: Alvarado *et al.*, In Press. Table 5)

Region	NCPO	NEPO	SWPO	SEPO
NCPO	-	0.0027	0.0081	0.0205
NEPO	**0.00239 (0.00070)**	-	0.0056	0.0185
SWPO	**0.01111 (0.00180)**	0.46940 (0.01044)	-	0.0678
SEPO	**0.00000 (0.00000)**	**0.00204 (0.00086)**	**0.00000 (0.00000)**	-

NCPO: central north Pacific Ocean; NEPO: north-eastern Pacific; SCPO: central south Pacific; SEPO: south-eastern Pacific; SWPO: south-western Pacific.