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Age Structured Stock Assessment of North Pacific Swordfish (*Xiphias gladius*) with Stock Syntheiss under a Two Stock Scenario

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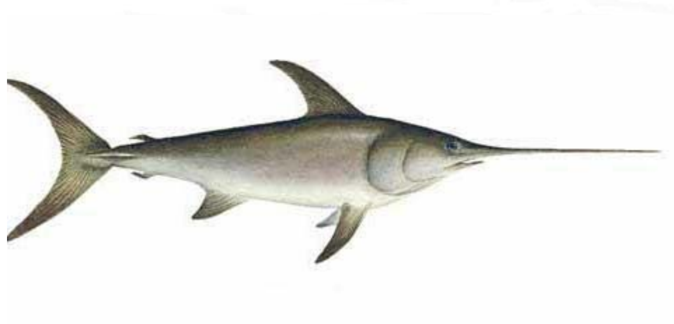

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Age Structured Stock Assessment of North Pacific Swordfish (*Xiphias gladius*) with Stock Synthesis under a Two Stock Scenario

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Abstract

This report summarizes Stock Synthesis model runs for a North Pacific Swordfish (*Xiphias gladius*) stock assessment under a two stock scenario. The stock structure assumed for this assessment was two stocks (Sub-Area 1 and Sub-Area 2) with a diagonal boundary from Baja, California (25ºN x 110ºW) to approximately 170ºW at the equator and no mixing between Sub-Areas. Model structure was based on preliminary age-structured stock assessments of North Pacific swordfish under a single stock scenario and a two stock scenario presented separately. Model results were compared to those from Bayesian production (BSP) models fit to the same data. The Stock Synthesis model for Sub-Area 1 appeared to adequately estimate selectivity for the major fisheries with some caveats, to fit CPUE time-series reasonably well, and to adequately fit length compositions from the major fisheries with some caveats. In contrast, the Stock Synthesis model for Sub-Area 2 had a relatively poor fit to the limited length frequency data and estimates of female spawning biomass and age-0 recruitment were highly uncertain. The Stock Synthesis model for Sub-Area 2 was also sensitive to the minor changes made to the model since the preliminary assessment and to the addition of updated catch data. Together, these results suggest that Stock Synthesis model results may be more reliable for Sub-Area 1 than for Sub-Area 2. Both models were consistent with model results from BSP in that ending year 2006 female spawning biomass was estimated above spawning biomass at maximum sustainable yield (MSY) and 2006 fishing mortality (F) was estimated below F at MSY.

1. Introduction

This report summarizes Stock Synthesis (SS) model runs for a North Pacific Swordfish (*Xiphias gladius*) stock assessment under a two stock scenario (Figure 1). Model structure was based on preliminary age-structured stock assessments of North Pacific swordfish under a single stock scenario (Courtney and Piner 2009a and 2009b) and a two stock scenario (Courtney and Piner 2009c). Model results were compared to those from Bayesian production (BSP) models fit to the same data (Brodziak and Ishimura 2009, BILL-WG 2009b, Brodziak 2010).

2. Methods

2.1 Stock Structure

The stock structure assumed for this assessment was a two-stock scenario (Figure 1) with no mixing between sub areas (BILL-WG 2008, BILL-WG 2009a, BILL-WG 2009b, BILL-WG 2009c). Sub areas were separated by a diagonal boundary from Baja California (25ºN x 110ºW) to approximately 170ºW at the equator (Figure 1). The boundary followed a stair step pattern modified from Ichinokawa and Brodziak (2008). The southern boundary of Sub-Area 1 in the western and central Pacific Ocean was at the equator. The southern boundary of Sub-Area 2 in the eastern Pacific Ocean was at 20ºS (Figure 1).

For Sub-Area 1, catch, CPUE, and length were incorporated into the assessment model using a regional spatial stratification modified from Sun et al. (2009) which included five regions (1-1, 1-2, 1-3, 1-4, 1-5) (BILL-WG 2009a, BILL-WG 2009b) (Figure 2). The rational for incorporating regional structure within Sub-Area 1 was that a smaller spatial scale more accurately reflected regional differences in catch at length in Stock Synthesis. The SS model structure for Sub-Area 1 was not spatially explicit; instead, SS modeled each fishery relative to the global population. An assumption was that all fisheries within a region sampled the same subset of the total stock so that they had the same apparent selectivity relative to the total stock. Another assumption was that movement between regions was sufficiently high so that the effects of catch in one region were instantaneously diffused among all other regions. Homogeneity in recruitment across regions was also assumed.

Sub-Area 2, consisted of one region (Figure 2).

2.2 Biological Parameters

For this analysis, independently estimated swordfish life history parameters from the Central North Pacific were input into Stock Synthesis as fixed parameters (Table 1). Length-at-age growth parameters (cm of eye-fork length), maximum age (TMAX y), and max eye fork length (cm) were taken from DeMartini et al. (2007), and Uchiyama and Humphreys (2007). Length-weight relationship for pooled sexes (cm of eye fork length, kg) were taken from Uchiyama et al. (1999), and Uchiyama and Humphreys (2007). Maturity probability at length p(L) in cm of eye fork length was taken from DeMartini et al. (2000). Combined values for von Bertalanffy growth parameters and maturity probability were not available from DeMartini et al. (2000). As a result, combined values for von Bertalanffy growth parameters and maturity probability were estimated here by fitting length-at-age growth models and maturity-at-length models to the sex-combined data in Excel and minimizing the sum of squared differences between observed and expected values (Table 1).

Estimates of natural mortality were linked to life history of swordfish from the Central North Pacific Ocean (BILL-WG 2009a) (Tables 2 and 3). Natural mortality estimates were obtained by taking the average of 4 age-independent estimates of M and 1 age-dependent estimate of M from (Brodziak 2009). Age-independent estimates of M followed methods from Hoenig (1983), Alverson and Carney (1975), Pauly (1980), and Beverton-Holt invariant 2 (Jensen 1996). Age-dependent estimates of M followed methods from the Lorenzen (1996) tropical system estimator. Separate estimates were made for female and male swordfish. Estimates for females and males combined were obtained as the average of male and female natural mortality rates at a quarterly time step.

Life history data were compiled separately for females (Table 4), males (Table 5) and females and males combined (Table 6). However, for this assessment, a single sex model was implemented because sexually specific length data were limited. Sex ratio data for Japan distant water longline fisheries were only available from training vessels which did not fish in the same location as the commercial fishery. As a result, the BILL-WG recommended not incorporating Japan distant water longline fisheries sex ratios in this assessment (BILL-WG 2009b). Sexually specific length composition data were only available for US Hawaii Longline (Brodziak and Courtney 2009, Courtney et al. 2009, Courtney and Fletcher 2009). Sexually specific length frequency data were limited and preliminary analysis indicated that the stock synthesis model was not sensitive to the addition of the limited sexually specific length frequency data available from US Hawaii Longline (Courtney and Piner 2009a). As a result, the BILL-WG recommended that a single sex model was more parsimonious (BILL-WG 2009b). Preliminary fits to length frequency were poor (BILL-WG 2009b), and Pacific swordfish growth rates during the first year are very high (DeMartini et al. 2007). As a result, a quarterly time step was implemented for this assessment in an effort to improve model fits to length frequency data.

2.3 Catch, Length, and CPUE

Sub-Area 1 included 23 fisheries, 9 time series of length frequency, and 3 time series of standardized CPUE (Tables 7.1, 8.1, and 9.1). Sub-Area 2 included 5 fisheries, 1 time series of length frequency, and 2 time series of standardized CPUE (Tables 7.2, 8.2, and 9.2). Catch and CPUE data were the same as compiled for a Bayesian production model (Courtney and Wagatsuma 2009, BILL-WG 2009c) (Figures 3.1 and 3.2), except that catch data for Sub-Area 2 (Figure 3.2) were updated at the BILL-WG (2009c) (Appendix A). Length data were compiled separately for Stock Synthesis (Courtney and Fletcher 2009).

For Sub-Area 1, catch for all Japan fleets (F1-F16) and U.S. Hawaii Longline (F29) were available at a quarterly time step (Jan-March, April-June, July-September, and October-December) (Table 7.1). Annual catch for Chinese Taipei Distant Water Longline (F19-F25) and Korea Longline (F26 and F27) were apportioned to quarters in the same ratios as Japan Offshore + Distant Water Longline catch in the same region (Table 7.1). Annual catches for US California Gillnet (F30), US California Longline (F31), and US California Other + Unknown (F32) were assigned to quarter four (Q4) which was consistent with the seasonal timing of swordfish catch (Ito and Childers 2008).

For Sub-Area 2, catch for Japan Offshore + Distant Water Longline (F1) was available at a quarterly time step (Jan-March, April-June, July-September, and October-December) (Table 7.2). Annual catch for Chinese Taipei Longline (F2) , Korea Longline (F3), and Spain Longline (F4) were apportioned to quarters in the same ratios as Japan Offshore + Distant Water Longline catch (F1) (Table 7.2). Annual catch for Mexico All Gears (F5) was assigned to Q4 (Table 7.2) which was consistent with the seasonal timing of swordfish catch (Ito and Childers 2008). The Mexico swordfish longline fleet operated in Mexican waters from September-October to February, and swordfish catches declined after February and were very scarce in the summer months of July and August (Fleischer et al. 2009). The seasonal timing of Mexico catch appeared to differ somewhat from that of Japan Offshore + Distant Water Longline in Sub-Area 2 (Table 7.2).

For Sub-Area 1, regionally stratified length frequency data were available for 9 combinations of fleets and regions (F1, F2, F3, F4, F5, F7, F12, F29, and F30) (Table 8.1). Because of limited sample size, quarterly length frequency data were only incorporated for Japan Offshore + Distant Water Longline (F1, F2, F4), US Hawaii Longline (F29), and US California Gillnet (F30) (Table 8.1). Annual length frequency data were incorporated for Japan Offshore + Distant Water Longline (F3 and F5), Japan Driftnet (F7), Japan Other, Primarily Harpoon (F12) and assigned to the quarter with most catch (Tables 7.1 and 8.1).

For Sub-Area 2, length frequency data were only available for Japan Offshore + Distant Water Longline (F1) (Table 8.2). Length frequency data were available at a quarterly resolution.

For Sub-Area 1, standardized time-series of CPUE were available for three fleets (S1, S8, and S15) (Table 9.1). Japan Offshore + Distant Water Longline CPUE was assigned to quarter 1 (Q1) based on the proportion of Japan Offshore + Distant Water Longline catch (mt) from 1990 - 2007 in Q1 (50%), Q2 (21%), Q3 (10%), Q4 (20%) (Tables 7.1 and 9.1). Chinese Taipei Distant Water Longline swordfish catch occurred primarily in region 1-4, and as a result, Chinese Taipei Distant Water Longline CPUE (S8) was assigned to Q2 based on the proportion of Japan Offshore + Distant Water Longline catch (mt) in region 1-4 (F4) by quarter from 1990 – 2007 Q1 (19%), Q2 (43%), Q3 (27%), Q4 (11%) (Tables 7.1 and 9.1). Hawaii longline shallow-set CPUE (S15) was assigned to Q2 based on the proportion of Hawaii longline catch (mt) (F29) by quarter from 1990 - 2007 Q1 (35%), Q2 (40%), Q3 (11%), Q4 (14%) (Tables 7.1 and 9.1).

For Sub-Area 2, Japan Offshore + Distant Water Longline CPUE (S1) and Chinese Taipei Distant Water Longline CPUE (S2) were assigned to Q4 based on the proportion of catch in Japan Offshore + Distant Water Longline (F1) by quarter from 1990 - 2007 Q1 (28%), Q2 (20%), Q3 (23%), Q4 (29%) (Tables 7.2 and 9.2).

2.4 Model Structure

The assessment was conducted with Stock Synthesis (SS) V3.02E-SAFE, 04/07/09, using Otter Research ADMB 7.0.13 by Richard Methot (NOAA) and available from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/SS.html) (Methot 2000).

Model structure was based on preliminary age-structured stock assessments of North Pacific swordfish under a single stock scenario (Courtney and Piner 2009a and 2009b) and a two stock scenario (Courtney and Piner 2009c).

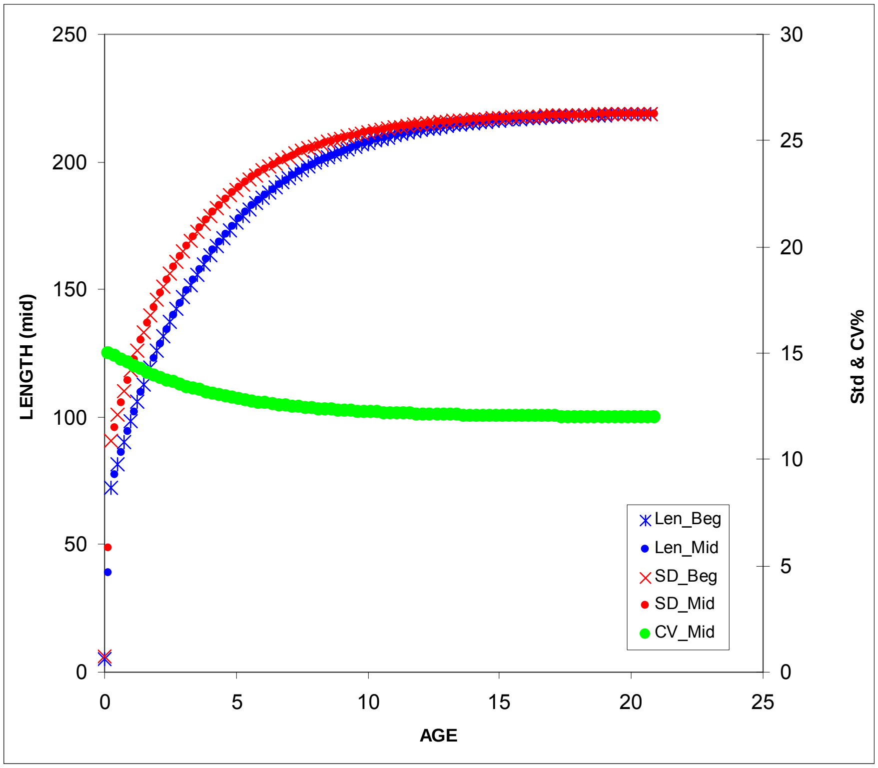
As a result of BILL-WG review of the age-structured model under a single stock scenario (BILLWG 2009b), the Stock Synthesis model for the two-stock scenario used a Beverton-Holt spawner-recruit relationship with steepness (h) fixed at 0.9; a standard error of the process error in recruitment (σ_r) fixed at 0.6 and iteratively re-weighted once to match the initial Stock Synthesis model estimate of Root Mean Squared Error (R.M.S.E.); and natural mortality (M) linked to life history (Table 10). For Sub-Area 1, the population was assumed to be in equilibrium prior to 1951 with an estimated equilibrium exploitation level approximated by average Japan Offshore + Distant Water Longline Catch (1951 – 1955) of 10,512 (mt). For Sub-Area 2, the population was assumed to be unfished prior to 1955.

For this assessment, swordfish spawning was assigned to quarter 2 (April, May, June) based on a review of larval occurrence (Table 10, Appendix B). Age at recruitment in Stock Synthesis will depend on estimated quarterly selectivity at length. For example, average quarterly selectivity at age (1990 – 2006) was calculated here from the estimated quarterly selectivity at length based on stock scenario 1, a single stock north of the equator (Courtney and Piner 2009b) (Figure B.1).

Main recruitment deviations were estimated from 1970 – 2006. The central tendency was bias corrected for process error in recruitment from 1960 – 1970 using a linear interpolation of σ_r beginning at 0 in 1960 and ending at the full value of σ_r in 1970. In order to avoid potential bias in the magnitude of main recruitment deviations near the beginning of the time series, early recruitment deviations were estimated from the start year (1951 for Sub-Area 1, and 1955 for Sub-Area 2) to 1970. The estimated standard deviation of each early recruitment deviation should be equal to σ_r except for the last few years which were influenced by length data which began in 1970. However, as a result of estimating early recruitment deviations, reported depletion levels during the early period (prior to 1970) may be biased and should be treated with caution when interpreted relative to the status of the stock.

The population model had 49 length bins (5 cm) from 20 – 260+ (cm). The fishery length data had 45 length bins (5 cm) from 40 to 260+ (cm). The population had 20 annual ages from 0 to 20.

There were no age data. Fishery length frequency data were used to estimate selectivity patterns which controlled the size (and age) distribution of fishery removals. The assumed CV for combined values of von Bertalanffy length at age was set to 0.15 for young fish and 0.12 for old fish.



CPUE indices were treated as survey indices and were assumed to be linearly proportional to available biomass, with constant catchability (q) assumed to occur halfway through the assigned quarter of the survey. Catch was assumed to be known without error and removed by estimating continuous fishing mortality (F) for each set of fleets with the same selectivity by region.

2.5 Length Based Selectivity

Length based selectivity was estimated for fleets with length frequency data. For Sub-Area 1, these included F1, F2, F3, F4, F5, F7, F12, F29, and F30 (Table 8.1). For Sub-Area 2, these included F1 (Table 8.2). We assumed that length based selectivity for fleets without length frequency data was the same as (mirrored) fleets with length frequency data within the same region. For Chinese Taipei Distant Water Longline, Korea Longline, Spain Longline, and Mexico All Gears, we assumed that the selectivity patterns mirrored those of Japan Offshore + Distant Water Longline in their respective regions (Tables 8.1 and 8.2). For US California Longline and US California Other Gear + Unknown, we assumed that selectivity patterns mirrored US California Gillnet (the only fleet in Region 1-3 with sufficient length data to estimate selectivity) (Tables 8.1 and 8.2).

Selectivity patterns for CPUE time series mirrored their respective fleet in the region with the highest proportion of catch (Tables 9.1 and 9.2).

For Sub-Area 1, all selectivity models were estimated as two parameter asymptotic logistic equations except for Japan Offshore + Distant Water Longline Region 1 (F1) which had a 6 parameter dome-shaped double normal model, and Japan Other Primarily Harpoon (F12) which had a modified 3 parameter asymptotic double normal model (Table 8.1). For Sub-Area 2, all selectivity models were estimated as two parameter asymptotic logistic equations (Table 8.2).

The rational for dome-shaped selectivity for Japan Offshore + Distant Water Longline (F1) in region 1-1 of Sub-Area 1 (Table 8.1 and Figure 2) was the relatively larger mode in length of swordfish captured in region 1-1 by the Japan Other Primarily Harpoon (F12) (Courtney and Piner 2009b). Including dome-shaped selectivity for Fleet 1 resulted in a better fit to the Japan Offshore + Distant Water longline length frequency data in region 1-1. The rational for including a modified 3 parameter asymptotic double normal model for Japan Other Primarily Harpoon (F12) was to force a maximum selectivity of 1, which allowed interpretation of resulting fishing mortality for fleet 12 to match those of the other fleets. Models run without a three parameter selectivity model for F12 were very sensitive to the selectivity pattern estimated for fleet 12, and resulted in maximum selectivity below 1 (Courtney and Piner 2009c). This may also have resulted from not setting parameter bounds correctly to accommodate the larger size range of this stock.

Selectivity parameters for the two parameter asymptotic logistic equation were estimated with a diffuse lognormal prior (Stdev = 999). Selectivity parameters for the double normal model were estimated with a diffuse symmetric beta prior (0.05).

Length based selectivity for Japan Offshore + Distant Water Longline was allowed to vary over three time periods (blocks) (start year – 1983, 1984 – 1993, 1994 – 2006) corresponding to changes in gear configuration during the years 1984-1990 and 1993-1995 (Ishimura et al. 2008, Okamoto and Bayliff 2003) (Tables 11.1 and 11.2). The timing of these breaks is also consistent with an independent analysis of the yearly change in hooks per basket of Japanese longline fisheries (Kanaiwa and Yokawa 2009). Length based selectivity was allowed to vary over two time periods (blocks) for US Hawaii Longline (1995 – 2003, 2004 – 2006) and US California Gillnet (1980 – 1999, 2000 – 2006) corresponding to management actions that may have affected length based selectivity (Ito and Childers 2008, Piner and Betcher 2009) (Table 11.1).

2.6 Effective Sample Size

Input standard errors for Japan Offshore + Distant Water Longline CPUE (S1) and Chinese Taipei Distant Water Longline CPUE (S8) were estimated from annual standard errors of GLM standardized CPUE (Courtney and Wagatsuma 2009). Input standard errors for US Hawaii Longline CPUE (S15) were estimated from annual standard errors of the ratio of GAM standardized catch to effort (Courtney and Wagatsuma 2009).

For Sub-Area 1, input standard errors for CPUE were iteratively re-weighted once to match the initial Stock Synthesis model estimate of Root Mean Squared Error (R.M.S.E.) for each CPUE time series (McAllister and Ianelli 1997, Piner et al. 2007a) (Table 12.1).

The Stock Synthesis model for Sub-Area 2 was sensitive to iteratively re-weighting CPUE. As a result, Sub-Area 2 input standard errors for CPUE were not iteratively re-weighted (Table 12.2). For example, when CPUE was iteratively re-weighted (Table 12.2), the very small standard error estimates for Chinese Taipei Distant Water Longline (S2) during the years 2001 – 2005 (Figure 5.2) dominated the likelihood and resulted in a non-random residual pattern in fit to Japan Offshore + Distant Water Longline CPUE (S1) during the years 1994-2006 (not shown). Chinese Taipei Distant Water Longline (S2) accounted for 9% of total swordfish catch (mt) in Sub-Area 2 from 1990 – 2007, while Japan Offshore + Distant Water Longline (S1) accounted for 62% (Table 7.2). As a result, we did not feel justified in forcing a better fit to Chinese Taipei Distant Water Longline that resulted in a poorer fit to Japan Offshore + Distant Water Longline (S1).

Fishery length frequency sample size was input as the square root of the number of fish measured. The square root transformed very large input sample sizes to a scale that approximated the R.M.S.E. effective mean sample size (Tables 12.1 and 12.2). Minimum sample size for length frequency data in the Stock Synthesis model was set at n = 100, for both annual and quarterly data, based on an ad-hoc review of the available length frequency data. If less than 100 fish were measured for length, then the length data were excluded from the model. The Stock Synthesis models for Sub-Area 1 and Sub-Area 2 were sensitive to iteratively re-weighting length frequency. As a result, Sub-Area 1 and Sub-Area 2 input sample sizes for length were not iteratively re-weighted (Tables 12.1 and 12.2). Alternative methods for estimating effective sample size for use in stock assessment models are under investigation (Shibano et al. 2010).

2.7 Evaluation of Stock Status

Maximum sustainable yield (MSY), female spawning biomass (S) at MSY (S_MSY), and fishing mortality (F) at MSY (F_MSY) were calculated relative to the selectivity regime in “zero state,” defined here as the time blocks which included the ending year 2006, and relative to the fixed value of steepness and an assumed 50:50 sex ratio. Model estimated time-series of female spawning biomass (S in metric tons, mt = 1,000 kg), recruitment (R in 1,000s of fish), total biomass (B mt), and age 2+ total biomass (B_2+ mt) were tabulated on an annual basis. Total annual exploitation rate was calculated as (Catch mt)/(B_2+ mt) for comparison to exploitable biomass estimated from BSP models. Age 2+ total biomass was used as a simple measure of the exploitable biomass because age 2 fish (125.8 cm EFL, Table 6) were approximately 50% fully selected (with near knife edge selectivity) in the major fisheries (Japan Offshore + Distant Water Longline in regions 1-1 and 1-2, Figures 7 and 8) (and e.g. Figure B.1).

MSY is commonly considered an upper bound for catch rather than a target. In particular, empirical evidence from production models has shown that populations have been exploited at levels higher than MSY before MSY could be estimated with precision (Hilborn and Walters 1992). Alternative biological reference points (BRPs) including spawning stock or egg production on a per-recruit basis have been recommended as a means to preserve reproductive potential of a population (Quinn and Deriso 1999), but were not considered here.

2.8 Convergence Criteria and Diagnostics

The model was assumed to have converged if the standard error of the parameter estimates could be derived from the inverse of the negative hessian matrix. Convergence diagnostics were also evaluated. Excessive CV's (StDev/Parm > 50%) on estimated quantities were indicative of uncertainty in parameter estimates or assumed model structure. The correlation matrix was examined for highly correlated (> 0.95) and non-informative (< 0.01) parameters. Parameters estimated at a bound were a diagnostic for possible problems with data or the assumed model structure. Individual likelihood component fits were evaluated for CPUE, length frequency, total recruitment, and the total objective function. Fits to CPUE and patterns in Pearson's residuals of fits to length frequency were examined as diagnostics for problems with data or the assumed model structure.

3. Model Results

Model results were evaluated with Microsoft Excel subroutines available for SS from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/SS.html) and with R statistical package plotting subroutines designed specifically for SS (r4ss Google Code, http://code.google.com/p/r4ss/).

3.1 Convergence Diagnostics

3.1.1 Sub-Area 1

The model for Sub-Area 1 took 1 hr and 58 minutes to run, had 119 parameters, a final objective function value of 1,670.02, and a maximum final gradient of 5.8×10^{-4}. Model execution for Sub-Area 1 could be improved with no loss of accuracy by combining the catch of all fisheries that share the same selectivity pattern (Table 8.1) and by assigning CPUE to a fishing fleet with length data rather than modeling CPUE as a mirrored fleet.

All 19 estimated early recruitment deviations, 1951 – 1969, and 21 of 36 (58%) of estimated main recruitment deviations, 1970 – 2005, had CVs > 50%.

Additionally, 13 of 51 (25%) estimated selectivity parameters had CVs > 50%. Twelve of these were from dome shaped selectivity for fleet F1 (Japan Offshore + Distant Water Longline in region 1-1) during the time blocks 1951 – 1983, 1984 – 1993, and 1994 – 2006 (Tables 8.1 and 11.1, Figures 2 and 7.1) and included parameters 2 (ascending width of the distribution), 4 (descending width of the distribution), 5 (initial intercept of the distribution), and 6 (final intercept of the distribution). One of these was parameter 5 (initial intercept of the distribution) from dome shaped selectivity for fleet F12 (Japan Other Primarily Harpoon in Region 1-1) during the year 2006 (Table 8.1 and Figure 9). These convergence diagnostics suggest that size selectivity for fleet F1 (Japan Offshore + Distant Water Longline in region 1-1) and fleet F12 (Japan Other Primarily Harpoon in Region 1-1) may need further investigation. Fleet F1 accounted for 43.19% and 16.80% of total catch from 1951 – 1983 and 1990 – 2007 respectively (Table 7.1), so problems fitting selectivity for F1 may be of concern. However, sensitivity analysis conducted for the single stock scenario indicated that model results were not sensitive to estimating dome-shaped selectivity compared to asymptotic selectivity for F1 (Japan Offshore + Distant Water Longline in region 1 (Courtney and Piner 2009b).

Eight parameters were below the threshold (0.01) for uncorrelated parameters. Six were from dome shaped selectivity for fleet F1, including parameter 2 during the time block 1994 – 2006, parameter 4 during the time blocks 1951 – 1983 and 1984 – 1993, and parameter 5 during the time blocks 1951 – 1983, 1984 – 1993, and 1994 – 2006 (Tables 8.1 and 11.1, Figures 2 and 7.1). Another was parameter 5 from dome shaped selectivity for fleet F12 during the year 2006 (Table 8.1 and Figure 9). Another was from logistic selectivity for fleet F3 (Japan Offshore + Distant Water Longline in region 1-3) during the years 1994 - 2006 (Table 8.1 and Figure 7.3). Parameters 2 and 4, from dome shaped selectivity for fleet F1 during the years 1951 – 1984, were above the correlation threshold (0.095). These convergence diagnostics also suggests that size selectivity for fleet F1 (Japan Offshore + Distant Water Longline in region 1-1) and fleet F12 (Japan Other Primarily Harpoon in Region 1-1) may need further investigation. They also suggest that there may not be sufficient length data to accurately estimate selectivity for fleet F3 (Japan Offshore + Distant Water Longline in region 1-3). Fleet F3 accounted for only 2.76% and 0.74% of total catch from 1951 – 1983 and 1990 – 2007 respectively (Table 7.1), so fleet F3 could be combined with another fleet.

3.1.2 Sub-Area 2

The model for Sub-Area 2 took 7 minutes to run, had 69 parameters, a final objective function value of 325.3, and a maximum final gradient component of 7.6 $x10^{-6}$. Eleven of fifteen (73%) of estimated early recruitment deviations, 1955 – 1969, and 33 of 36 (92%) of estimated main recruitment deviations, 1970 – 2005, had CVs > 50%. One parameter, main recruitment deviation in 1979, was below the threshold (0.01) for uncorrelated parameters.

3.2 Model Fits

3.2.1 Sub-Area 1

For Sub-Area 1, fits to Japan Offshore + Distant Water Longline CPUE (S1; Table 9.1 and Figure 4.1) were improved (-28 likelihood units) relative to the preliminary assessment (Courtney and Piner 2009c) (Table 15.1). Fits to Chinese Taipei Distant Water Longline CPUE (S8), U.S. Hawaii Longline CPUE (S15) and all length frequency data were about the same as the preliminary assessment (Courtney and Piner 2009c) (Figures 5.1 and 6.1, Tables 15.1 and 16.1).

Pearson residuals for quarterly fits to length frequency from fleet F1 (Japan Offshore + Distant Water Longline in region 1-1) (Table 8.1 and Figure 2) indicated that the model underestimated the number of small fish during many year/quarters and the number of large fish after 1984 (Figure 12.1). Pearson residuals for quarterly fits to length frequency from fleet F2 (Japan Offshore + Distant Water Longline in region 1-2) indicated that the model underestimated the number of small fish in many year/quarters and underestimated the number of fish at the peak (~ 150 cm eye fork length) during apparent recruitment events in the late 1990s and early 2000s (Figure 12.2). Pearson residuals for length frequency summarized annually for all Japan Offshore + Distant Water Longline fleets (F1, F2, F3, F4, and F5) combined indicated that the model underestimated the number of small fish (75 cm to 100 cm EFL) during most years (Figures 12.7.1A and 12.7.1B).

Model fits to US Hawaii Longline length frequency showed trends in Pearson residuals associated with an apparent recruitment event in the late 1990s (Figure 15). Model fits to US California Gillnet length frequency underestimated the number of large fish prior to 1995 (Figure 16).

3.2.2 Sub-Area 2

For Sub-Area 2, fits to Japan Offshore + Distant Water Longline CPUE (S1; Table 9.2 and Figure 4.2) were improved (-14 likelihood units) relative to the preliminary assessment (Courtney and Piner 2009c) (Table 15.2). Fits to Chinese Taipei Distant Water Longline CPUE (S2) were also improved (-168 likelihood units) relative to the preliminary assessment (Courtney and Piner 2009c) (Table 15.2). However, this may have been an artifact of increasing the variance within the likelihood component by not iteratively reweighting CPUE from the input standard errors (Table 10). Model fits to length frequency data were about the same (+ 1.4 likelihood units) relative to the preliminary assessment (Courtney and Piner 2009c) (Table 16.2).

For Sub-Area 2, the scale of Pearson residuals for fits to length frequency data was much larger (max 26, F1, Figure 12.6) than for Sub-Area 1 (max 8, F1, Figure 12.1) indicating a relatively poorer fit to length frequency data for Sub-Area 2. Model fits to length frequency data from Japan Offshore + Distant Water Longline in region 2-1 underestimated the number of small fish in many year/quarters (Figures 12.6, and 12.7.2B). There were also fewer predicted fish at the peak in length frequency (~150 cm eye fork length) than observed during some years (e.g., 1974, 1975, 1982, 1983, and 1989) (Figures 12.7.2A and 12.7.2B).

3.3 Estimated Time Series

3.3.1 Sub-Area 1

Sub-Area 1 model estimated time series of total biomass, age 2+ biomass, and female spawning biomass declined from 1951 to the mid 1960s, increased gradually to the early 1990's, and then declined gradually to the present (Table 13.1, Figures 17 – 19).

Sub-Area 1 age-0 recruitment variability was consistent with the availability of length frequency data which began in 1970 (Figure 20.1). Model estimation of early recruitment 1951 – 1970 moved from the central tendency about 10 years prior to 1970 as length frequency data from older fish available starting in 1970 began to influence the estimates. There was limited data at low population size to estimate the spawner-recruit relationship (Figure 21.1).

3.3.2 Sub-Area 2

Sub-Area 2 model estimated time series of total biomass, age 2+ biomass, and female spawning biomass (Table 13.2, Figures 17 - 19) mirrored trends in standardized CPUE time series for Japan Offshore + Distant Water Longline (S1) (Figure 4.2). Estimates of female spawning biomass and age-0 recruitment for Sub-Area 2 were highly uncertain (Figures 19.2, 20.2, and 23.2). This was consistent with the more limited length frequency data available for Sub-Area 2 (Table 8.2). Trends in female spawning biomass and age-0 recruitment were essentially flat when considered within the context of the high estimation error (Figures 19.2, 20.2, and 23.2). There was limited data at low population size to estimate the spawner-recruit relationship (Figure 21.2).

3.4 Stock Status

3.4.1 Sub-Area 1

Sub-Area 1 model estimated female spawning biomass was above MSY for all years from 1951 – 1957 and 1965 – 2006 (Tables 13.1 and 18.1, Figures 22.1 and 23.1). Model estimated fishing mortality (F) was above F_MSY from 1957 – 1972 and 1976, and has fluctuated below F_MSY since 1977 (Tables 14.1 and 18.1, Figures 22.1 and 24.1). Model estimated ending year female spawning biomass (S_2006) as a proportion of unfished female spawning biomass (S_0) was 28% (Table 17.1). Annual fishing mortality summed over all fleets and quarters and averaged from 1995-2006 (F_Avg 1995-2006) was 0.68 (Table 18.1). Average fishing mortality (F_Avg 1995-2006) was below the estimated F at MSY (F_Avg 1995-2006 / F_MSY = 0.76) (Table 18.1). Average fishing mortality (F_Avg 1995-2006 = 0.68) was higher than male and female natural mortality (M) which ranged from 0.40 at age 0.25 to 0.35 at older ages (Table 6).

Stock status for Sub-Area 1 estimated from this assessment was consistent with the preliminary assessment (Courtney and Piner 2009c) and model estimates of stock status were not sensitive to the minor changes made to the model since the preliminary assessment (Tables 17.1 and 18.1).

3.4.2 Sub-Area 2

The Sub-Area 2 model estimated female spawning biomass was above MSY for all years from 1955 – 2006 (Tables 13.2 and 18.2, Figures 22.2 and 23.2). Model estimated fishing mortality (F) was below F_MSY for all years (Tables 14.2 and 18.2, Figures 22.2 and 24.2). Model estimated ending year female spawning biomass (S_2006) as a proportion of unfished female spawning biomass (S_0) was 92% (Table 17.2). Annual fishing mortality summed over all fleets and quarters and averaged from 1995-2006 (F_Avg 1995-2006 was 0.07 (Table 18.2). Average fishing mortality (F_Avg 1995-2006) was below the estimated F at MSY (F_Avg 1995-2006 / F_MSY = 0.13) (Table 18.2). Average fishing mortality (F_Avg 1995-2006 = 0.07) was lower than male and female natural mortality (M) which ranged from 0.40 at age 0.25 to 0.35 at older ages (Table 6).

For Sub-Area 2, likelihood component fits for CPUE (Table 15.2) and resulting estimates of stock status (Tables 17.2 and 18.2) were sensitive to the minor changes made to the model since the preliminary assessment (Courtney and Piner 2009c) and the addition of updated catch data resulting in very different estimates of total stock size.

Together, the relatively poor fit to the limited length frequency data (Section 3.2.2, Figure 12.6), the highly uncertain estimates of female spawning biomass and age-0 recruitment (Section 3.3.2, Figures 19.2, 20.2, and 23.2), and the model sensitivity to the relatively minor changes made to the model since the preliminary assessment and to the addition of updated catch data (Tables 15.2, 17.2 and 18.2), suggest that the Stock Synthesis model for Sub-Area 2 may not provide reliable estimates of stock status in Sub-Area 2.

3.5 Stock Status estimated with SS relative to BSP

3.5.1 Sub-Area 1

Sub-Area 1 Stock Synthesis model estimates of age 2+ biomass were lower (outside the 95% Bayesian credible intervals) than time-series of exploitable biomass estimated with Bayesian surplus production (BSP) models run on the same data (Table 13.1, Figure 25.1). As a result estimated harvest rate from Stock Synthesis was higher than BSP (Table 14.1, Figure 26.1). Stock Synthesis model estimates of exploitable biomass were most consistent with BSP during recent years (~1999 – 2006) (Figure 25.1).

As a result of estimating early recruitment deviations in SS, reported depletion levels from SS during the early period (prior to 1970) may be biased and should be treated with caution when interpreted relative to the status of the stock. The assumed equilibrium catch of 10,512 mt in SS for Sub-Area 1 prior to 1951 may also have influenced depletion levels estimated by SS during early years.

3.5.2 Sub-Area 2

Sub-Area 2 Stock Synthesis model estimates of age 2+ biomass were higher than time-series of exploitable biomass estimated with BSP models run on the same data but inside the 95% Bayesian credible intervals after 1990 (Table 13.2, Figure 25.2). Stock Synthesis model estimates of exploitable biomass were most consistent with BSP during recent years (~1999 – 2006) (Figure 25.2). Trends in harvest rate were nearly identical for Stock Synthesis and BSP model estimates (Table 14.2 and Figure 26.2).

4. Conclusions

4.1 Sub-Area 1

For Sub-Area 1, ending year 2006 spawning biomass was estimated above spawning biomass at maximum sustainable yield (MSY) and 2006 fishing mortality (F) was estimated below F at MSY (Figures 22 – 24).

The Stock Synthesis model for Sub-Area 1 appeared to adequately estimate selectivity for the major fisheries and to fit CPUE series well enough to scale the absolute abundance estimates (Figures 4 – 11). Uncertainty in the selectivity estimated for fleet F12 (Japan Other Primarily Harpoon in Region 1-1) and fleet F1 (Japan Offshore + Distant Water Longline in region 1-1) during the time blocks 1951 – 1983, 1984 – 1993, and 1994 – 2006 suggests that the selectivity patterns for these fleets may need further investigation. However, sensitivity analysis conducted for the single stock scenario indicated that model results were not sensitive to estimating dome-shaped selectivity compared to asymptotic selectivity for F1 (Japan Offshore + Distant Water Longline in region 1 (Courtney and Piner 2009b). The Stock Synthesis model for Sub-Area 1 appeared to adequately fit length compositions from the major fisheries (Figures 12 – 16).

Evaluation of stock status for Sub-Area 1 from Stock Synthesis and BSP models gave similar results. Namely, ending year 2006 spawning biomass was estimated above spawning biomass at maximum sustainable yield (MSY) and 2006 fishing mortality (F) was estimated below F at MSY (Brodziak and Ishimura 2009, BILL-WG 2009b). However, relative to the BSP model, Stock Synthesis results from Sub-Area 1 indicated lower biomass and higher harvest rates (often outside 95% BSP Bayesian credible intervals) (Figures 25 – 26). The relatively higher depletion levels estimated from Stock Synthesis during the early period (prior to 1970) may be biased due to estimation of early recruitment deviations in SS and should be treated with caution when interpreted relative to the status of the stock. Also, the assumed equilibrium catch of 10,512 mt in SS for Sub-Area 1 prior to 1951 may have influenced depletion levels estimated by SS during early years.

4.2 Sub-Area 2

Together, the relatively poor fit to the limited length frequency data (Section 3.2.2, Figure 12.6), the highly uncertain estimates of female spawning biomass and age-0 recruitment (Section 3.3.2, Figures 19.2, 20.2, and 23.2), and the model sensitivity to the relatively minor changes made to the model since the preliminary assessment and to the addition of updated catch (Tables 15.2, 17.2 and 18.2), suggest that the Stock Synthesis model for Sub-Area 2 may not provide reliable estimates of stock status in Sub-Area 2.

The Sub-Area 2 model had more limited length frequency data and had a relatively poor fit to the limited length frequency data (Figure 12.6). Estimates of female spawning biomass and age-0 recruitment for Sub-Area 2 were highly uncertain (Figures 19.2, 20.2, and 23.2). This was consistent with the more limited length frequency data available for Sub-Area 2 (Table 8.2). Stock status for Sub-Area 2 estimated from this assessment with Stock Synthesis was also not consistent with the stock status estimated from the preliminary assessment with Stock Synthesis (Courtney and Piner 2009c). This indicates that model estimates of stock status were sensitive to the changes made to the model since the preliminary assessment (Tables 17.2 and 18.2).

However, evaluation of stock status for Sub-Area 2 from Stock Synthesis and BSP models gave similar results. Namely, ending year 2006 spawning biomass was estimated above spawning biomass at maximum sustainable yield (MSY) and 2006 fishing mortality (F) was estimated below F at MSY (Brodziak and Ishimura 2009, BILL-WG 2009b).

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Table 1. Central North Pacific swordfish life history parameters estimated independently.

Life History Parameter	Female Value	Male Value	Combined Value*	Equation/Source
Central North Pacific Von Bertalanffy growth parameters (cm of eye-fork length)	K = 0.246 ± 0.019 LINF = 230.5 ± 3.94 T0 = -1.24 ± 0.167	K = 0.271 ± 0.034 LINF = 208.9 ± 5.60 T0 = -1.37 ± 0.259	K = 0.257 LINF = 219.7 T0 = -1.31	$EFL_t = EFL_\infty\left(1-e^{-k(t-t_0)}\right)$ Uchiyama and Humphreys (2007), DeMartini et al (2007)
Central North Pacific maximum observed age TMAX (y), and Max eye frok length (cm)	TMAX (y) = 12 Max (EFL) = 259	TMAX (y) = 11 Max (EFL) = 229		Uchiyama and Humphreys (2007), DeMartini et al (2007)
Central North Pacific length-weight relationship pooled sexes (cm of eye fork length, kg)	a = $1.2988\text{x}10^{-5}$ b = 3.0738			$W(kg) = aEFL^b$ Uchiyama and Humphreys (2007), Uchiyama et al. (1999)
Central North Pacific maturity probability (p(L) at length (cm of eye fork length)	L50 = 143.6 σ = 9.67	L50 = 102.0 σ = 7.08	L50 = 121.1 σ = 15.9	$p(EFL) = \left(1+\exp\left(\frac{-(EFL-L_{50})}{\sigma_m}\right)\right)^{-1}$ De Martini et al. (2000)

* Combined values for von Bertalanffy growth parameters and maturity probability were obtained by fitting the respective models to combined data in Excel and minimizing the squared differences between observed and expected values.

Table 2. Estimates of female swordfish natural mortality rates at age linked to life history of Central North Pacific swordfish (adapted from Brodziak 2009).

Age (yrqtr)	Female Weight (kg)	Hoenig 1983	Alverson and Carney (1975)	Pauly (1980)	Beverton-Holt invariant 2 (Jensen 1996)	Lorenzen (1996) tropical system estimator	Mean
0.25	6.3	0.35	0.36	0.35	0.37	0.49	0.38
0.5	9.3	0.35	0.36	0.35	0.37	0.45	0.38
0.75	12.9	0.35	0.36	0.35	0.37	0.42	0.37
1	17.0	0.35	0.36	0.35	0.37	0.40	0.37
1.25	21.6	0.35	0.36	0.35	0.37	0.38	0.36
1.5	26.6	0.35	0.36	0.35	0.37	0.36	0.36
1.75	32.0	0.35	0.36	0.35	0.37	0.35	0.36
2	37.7	0.35	0.36	0.35	0.37	0.34	0.35
2.25	43.7	0.35	0.36	0.35	0.37	0.33	0.35
2.5	49.8	0.35	0.36	0.35	0.37	0.32	0.35
2.75	56.1	0.35	0.36	0.35	0.37	0.31	0.35
3	62.5	0.35	0.36	0.35	0.37	0.30	0.35
3.25	69.0	0.35	0.36	0.35	0.37	0.30	0.35
3.5	75.4	0.35	0.36	0.35	0.37	0.29	0.34
3.75	81.9	0.35	0.36	0.35	0.37	0.29	0.34
4	88.2	0.35	0.36	0.35	0.37	0.28	0.34
4.25	94.5	0.35	0.36	0.35	0.37	0.28	0.34
4.5	100.7	0.35	0.36	0.35	0.37	0.27	0.34
4.75	106.8	0.35	0.36	0.35	0.37	0.27	0.34
5	112.7	0.35	0.36	0.35	0.37	0.27	0.34
5.25	118.5	0.35	0.36	0.35	0.37	0.26	0.34
5.5	124.1	0.35	0.36	0.35	0.37	0.26	0.34
5.75	129.5	0.35	0.36	0.35	0.37	0.26	0.34
6	134.8	0.35	0.36	0.35	0.37	0.26	0.34
6.25	139.9	0.35	0.36	0.35	0.37	0.26	0.34
6.5	144.7	0.35	0.36	0.35	0.37	0.25	0.34
6.75	149.4	0.35	0.36	0.35	0.37	0.25	0.34
7	153.9	0.35	0.36	0.35	0.37	0.25	0.34
7.25	158.3	0.35	0.36	0.35	0.37	0.25	0.34
7.5	162.4	0.35	0.36	0.35	0.37	0.25	0.34
7.75	166.4	0.35	0.36	0.35	0.37	0.25	0.34
8	170.1	0.35	0.36	0.35	0.37	0.25	0.34
8.25	173.8	0.35	0.36	0.35	0.37	0.24	0.33
8.5	177.2	0.35	0.36	0.35	0.37	0.24	0.33
8.75	180.5	0.35	0.36	0.35	0.37	0.24	0.33
9	183.6	0.35	0.36	0.35	0.37	0.24	0.33
9.25	186.5	0.35	0.36	0.35	0.37	0.24	0.33
9.5	189.4	0.35	0.36	0.35	0.37	0.24	0.33
9.75	192.0	0.35	0.36	0.35	0.37	0.24	0.33
10	194.6	0.35	0.36	0.35	0.37	0.24	0.33
10.25	197.0	0.35	0.36	0.35	0.37	0.24	0.33
10.5	199.3	0.35	0.36	0.35	0.37	0.24	0.33
10.75	201.4	0.35	0.36	0.35	0.37	0.24	0.33
11	203.5	0.35	0.36	0.35	0.37	0.24	0.33
11.25	205.4	0.35	0.36	0.35	0.37	0.24	0.33
11.5	207.2	0.35	0.36	0.35	0.37	0.24	0.33
11.75	209.0	0.35	0.36	0.35	0.37	0.24	0.33
12	210.6	0.35	0.36	0.35	0.37	0.23	0.33
12.25	212.2	0.35	0.36	0.35	0.37	0.23	0.33
12.5	213.6	0.35	0.36	0.35	0.37	0.23	0.33
12.75	215.0	0.35	0.36	0.35	0.37	0.23	0.33
13	216.3	0.35	0.36	0.35	0.37	0.23	0.33
13.25	217.6	0.35	0.36	0.35	0.37	0.23	0.33
13.5	218.7	0.35	0.36	0.35	0.37	0.23	0.33
13.75	219.8	0.35	0.36	0.35	0.37	0.23	0.33
14	220.9	0.35	0.36	0.35	0.37	0.23	0.33
14.25	221.8	0.35	0.36	0.35	0.37	0.23	0.33
14.5	222.8	0.35	0.36	0.35	0.37	0.23	0.33
14.75	223.6	0.35	0.36	0.35	0.37	0.23	0.33
15	224.4	0.35	0.36	0.35	0.37	0.23	0.33

Table 3. Estimates of male swordfish natural mortality rates at age linked to life history of Central North Pacific swordfish (adapted from Brodziak 2009).

Age (yrqtr)	Male Weight (kg)	Hoenig 1983	Alverson and Carney (1975)	Pauly (1980)	Beverton-Holt invariant 2 (Jensen 1996)	Lorenzen (1996) tropical system estimator	Mean
0.25	7.3	0.38	0.39	0.38	0.41	0.48	0.41
0.5	10.3	0.38	0.39	0.38	0.41	0.44	0.40
0.75	13.8	0.38	0.39	0.38	0.41	0.42	0.40
1	17.7	0.38	0.39	0.38	0.41	0.39	0.39
1.25	21.9	0.38	0.39	0.38	0.41	0.38	0.39
1.5	26.5	0.38	0.39	0.38	0.41	0.36	0.38
1.75	31.3	0.38	0.39	0.38	0.41	0.35	0.38
2	36.3	0.38	0.39	0.38	0.41	0.34	0.38
2.25	41.4	0.38	0.39	0.38	0.41	0.33	0.38
2.5	46.6	0.38	0.39	0.38	0.41	0.32	0.38
2.75	51.9	0.38	0.39	0.38	0.41	0.32	0.38
3	57.1	0.38	0.39	0.38	0.41	0.31	0.37
3.25	62.4	0.38	0.39	0.38	0.41	0.30	0.37
3.5	67.5	0.38	0.39	0.38	0.41	0.30	0.37
3.75	72.6	0.38	0.39	0.38	0.41	0.29	0.37
4	77.6	0.38	0.39	0.38	0.41	0.29	0.37
4.25	82.5	0.38	0.39	0.38	0.41	0.29	0.37
4.5	87.2	0.38	0.39	0.38	0.41	0.28	0.37
4.75	91.7	0.38	0.39	0.38	0.41	0.28	0.37
5	96.2	0.38	0.39	0.38	0.41	0.28	0.37
5.25	100.4	0.38	0.39	0.38	0.41	0.27	0.37
5.5	104.5	0.38	0.39	0.38	0.41	0.27	0.37
5.75	108.4	0.38	0.39	0.38	0.41	0.27	0.37
6	112.2	0.38	0.39	0.38	0.41	0.27	0.37
6.25	115.8	0.38	0.39	0.38	0.41	0.27	0.37
6.5	119.2	0.38	0.39	0.38	0.41	0.26	0.36
6.75	122.4	0.38	0.39	0.38	0.41	0.26	0.36
7	125.5	0.38	0.39	0.38	0.41	0.26	0.36
7.25	128.5	0.38	0.39	0.38	0.41	0.26	0.36
7.5	131.3	0.38	0.39	0.38	0.41	0.26	0.36
7.75	133.9	0.38	0.39	0.38	0.41	0.26	0.36
8	136.4	0.38	0.39	0.38	0.41	0.26	0.36
8.25	138.8	0.38	0.39	0.38	0.41	0.26	0.36
8.5	141.0	0.38	0.39	0.38	0.41	0.26	0.36
8.75	143.1	0.38	0.39	0.38	0.41	0.25	0.36
9	145.1	0.38	0.39	0.38	0.41	0.25	0.36
9.25	147.0	0.38	0.39	0.38	0.41	0.25	0.36
9.5	148.8	0.38	0.39	0.38	0.41	0.25	0.36
9.75	150.4	0.38	0.39	0.38	0.41	0.25	0.36
10	152.0	0.38	0.39	0.38	0.41	0.25	0.36
10.25	153.5	0.38	0.39	0.38	0.41	0.25	0.36
10.5	154.9	0.38	0.39	0.38	0.41	0.25	0.36
10.75	156.2	0.38	0.39	0.38	0.41	0.25	0.36
11	157.4	0.38	0.39	0.38	0.41	0.25	0.36
11.25	158.6	0.38	0.39	0.38	0.41	0.25	0.36
11.5	159.6	0.38	0.39	0.38	0.41	0.25	0.36
11.75	160.6	0.38	0.39	0.38	0.41	0.25	0.36
12	161.6	0.38	0.39	0.38	0.41	0.25	0.36
12.25	162.5	0.38	0.39	0.38	0.41	0.25	0.36
12.5	163.3	0.38	0.39	0.38	0.41	0.25	0.36
12.75	164.1	0.38	0.39	0.38	0.41	0.25	0.36
13	164.9	0.38	0.39	0.38	0.41	0.25	0.36
13.25	165.5	0.38	0.39	0.38	0.41	0.25	0.36
13.5	166.2	0.38	0.39	0.38	0.41	0.25	0.36
13.75	166.8	0.38	0.39	0.38	0.41	0.25	0.36
14	167.4	0.38	0.39	0.38	0.41	0.25	0.36
14.25	167.9	0.38	0.39	0.38	0.41	0.25	0.36
14.5	168.4	0.38	0.39	0.38	0.41	0.25	0.36
14.75	168.9	0.38	0.39	0.38	0.41	0.25	0.36
15	169.3	0.38	0.39	0.38	0.41	0.25	0.36

Table 4. Central North Pacific female swordfish life history.

Age Class (yrqtr)	Female Length (cm)	Female Weight (kg)	Female Fraction Mature	Female Natural Mortality (Life History Mean Table 2)
0.25	71	6.3	0.00	0.38
0.5	80	9.3	0.00	0.38
0.75	89	12.9	0.00	0.37
1	98	17.0	0.01	0.37
1.25	106	21.6	0.02	0.36
1.5	113	26.6	0.04	0.36
1.75	120	32.0	0.08	0.36
2	127	37.7	0.15	0.35
2.25	133	43.7	0.25	0.35
2.5	139	49.8	0.37	0.35
2.75	144	56.1	0.51	0.35
3	149	62.5	0.64	0.35
3.25	154	69.0	0.75	0.35
3.5	159	75.4	0.83	0.34
3.75	163	81.9	0.88	0.34
4	167	88.2	0.92	0.34
4.25	171	94.5	0.94	0.34
4.5	174	100.7	0.96	0.34
4.75	178	106.8	0.97	0.34
5	181	112.7	0.98	0.34
5.25	184	118.5	0.98	0.34
5.5	187	124.1	0.99	0.34
5.75	189	129.5	0.99	0.34
6	192	134.8	0.99	0.34
6.25	194	139.9	0.99	0.34
6.5	196	144.7	1.00	0.34
6.75	198	149.4	1.00	0.34
7	200	153.9	1.00	0.34
7.25	202	158.3	1.00	0.34
7.5	204	162.4	1.00	0.34
7.75	205	166.4	1.00	0.34
8	207	170.1	1.00	0.34
8.25	208	173.8	1.00	0.33
8.5	210	177.2	1.00	0.33
8.75	211	180.5	1.00	0.33
9	212	183.6	1.00	0.33
9.25	213	186.5	1.00	0.33
9.5	214	189.4	1.00	0.33
9.75	215	192.0	1.00	0.33
10	216	194.6	1.00	0.33
10.25	217	197.0	1.00	0.33
10.5	218	199.3	1.00	0.33
10.75	218	201.4	1.00	0.33
11	219	203.5	1.00	0.33
11.25	220	205.4	1.00	0.33
11.5	220	207.2	1.00	0.33
11.75	221	209.0	1.00	0.33
12	222	210.6	1.00	0.33
12.25	222	212.2	1.00	0.33
12.5	223	213.6	1.00	0.33
12.75	223	215.0	1.00	0.33
13	224	216.3	1.00	0.33
13.25	224	217.6	1.00	0.33
13.5	224	218.7	1.00	0.33
13.75	225	219.8	1.00	0.33
14	225	220.9	1.00	0.33
14.25	225	221.8	1.00	0.33
14.5	226	222.8	1.00	0.33
14.75	226	223.6	1.00	0.33
15	226	224.4	1.00	0.33

Table 5. Central North Pacific male swordfish life history.

Age Class (yrqtr)	Male Length (cm)	Male Weight (kg)	Male Fraction Mature	Male Natural Mortality (Life History Mean Table 3)
0.25	74	7.3	0.02	0.41
0.5	83	10.3	0.06	0.40
0.75	91	13.8	0.18	0.40
1	99	17.7	0.40	0.39
1.25	106	21.9	0.64	0.39
1.5	113	26.5	0.82	0.38
1.75	119	31.3	0.92	0.38
2	125	36.3	0.96	0.38
2.25	131	41.4	0.98	0.38
2.5	136	46.6	0.99	0.38
2.75	141	51.9	1.00	0.38
3	145	57.1	1.00	0.37
3.25	149	62.4	1.00	0.37
3.5	153	67.5	1.00	0.37
3.75	157	72.6	1.00	0.37
4	160	77.6	1.00	0.37
4.25	163	82.5	1.00	0.37
4.5	166	87.2	1.00	0.37
4.75	169	91.7	1.00	0.37
5	172	96.2	1.00	0.37
5.25	174	100.4	1.00	0.37
5.5	176	104.5	1.00	0.37
5.75	179	108.4	1.00	0.37
6	181	112.2	1.00	0.37
6.25	182	115.8	1.00	0.37
6.5	184	119.2	1.00	0.36
6.75	186	122.4	1.00	0.36
7	187	125.5	1.00	0.36
7.25	189	128.5	1.00	0.36
7.5	190	131.3	1.00	0.36
7.75	191	133.9	1.00	0.36
8	192	136.4	1.00	0.36
8.25	193	138.8	1.00	0.36
8.5	195	141.0	1.00	0.36
8.75	195	143.1	1.00	0.36
9	196	145.1	1.00	0.36
9.25	197	147.0	1.00	0.36
9.5	198	148.8	1.00	0.36
9.75	199	150.4	1.00	0.36
10	199	152.0	1.00	0.36
10.25	200	153.5	1.00	0.36
10.5	201	154.9	1.00	0.36
10.75	201	156.2	1.00	0.36
11	202	157.4	1.00	0.36
11.25	202	158.6	1.00	0.36
11.5	203	159.6	1.00	0.36
11.75	203	160.6	1.00	0.36
12	203	161.6	1.00	0.36
12.25	204	162.5	1.00	0.36
12.5	204	163.3	1.00	0.36
12.75	204	164.1	1.00	0.36
13	205	164.9	1.00	0.36
13.25	205	165.5	1.00	0.36
13.5	205	166.2	1.00	0.36
13.75	205	166.8	1.00	0.36
14	206	167.4	1.00	0.36
14.25	206	167.9	1.00	0.36
14.5	206	168.4	1.00	0.36
14.75	206	168.9	1.00	0.36
15	206	169.3	1.00	0.36

Table 6. Central North Pacific combined female and male swordfish life history input to Stock Synthesis.

Age Class (yrqtr)	Combined Female and Male Length (cm)	Combined Female and Male Weight (kg)	Combined Female and Male Fraction Mature	Average Female and Male Natural Mortality (Life History Mean of Tables 2 and 3)
0.25	72	6.8	0.01	0.40
0.5	82	9.8	0.03	0.39
0.75	90	13.3	0.09	0.38
1	98	17.3	0.20	0.38
1.25	106	21.8	0.33	0.37
1.5	113	26.5	0.43	0.37
1.75	120	31.6	0.50	0.37
2	126	37.0	0.56	0.37
2.25	132	42.5	0.61	0.36
2.5	137	48.2	0.68	0.36
2.75	142	54.0	0.75	0.36
3	147	59.8	0.82	0.36
3.25	152	65.7	0.87	0.36
3.5	156	71.5	0.91	0.36
3.75	160	77.2	0.94	0.36
4	164	82.9	0.96	0.36
4.25	167	88.5	0.97	0.36
4.5	170	94.0	0.98	0.35
4.75	173	99.3	0.99	0.35
5	176	104.4	0.99	0.35
5.25	179	109.5	0.99	0.35
5.5	182	114.3	0.99	0.35
5.75	184	119.0	1.00	0.35
6	186	123.5	1.00	0.35
6.25	188	127.8	1.00	0.35
6.5	190	132.0	1.00	0.35
6.75	192	135.9	1.00	0.35
7	194	139.7	1.00	0.35
7.25	195	143.4	1.00	0.35
7.5	197	146.8	1.00	0.35
7.75	198	150.1	1.00	0.35
8	200	153.3	1.00	0.35
8.25	201	156.3	1.00	0.35
8.5	202	159.1	1.00	0.35
8.75	203	161.8	1.00	0.35
9	204	164.3	1.00	0.35
9.25	205	166.8	1.00	0.35
9.5	206	169.1	1.00	0.35
9.75	207	171.2	1.00	0.35
10	208	173.3	1.00	0.35
10.25	208	175.2	1.00	0.35
10.5	209	177.1	1.00	0.35
10.75	210	178.8	1.00	0.35
11	210	180.4	1.00	0.35
11.25	211	182.0	1.00	0.35
11.5	211	183.4	1.00	0.35
11.75	212	184.8	1.00	0.35
12	212	186.1	1.00	0.35
12.25	213	187.3	1.00	0.35
12.5	213	188.5	1.00	0.35
12.75	214	189.6	1.00	0.35
13	214	190.6	1.00	0.35
13.25	214	191.6	1.00	0.35
13.5	215	192.5	1.00	0.35
13.75	215	193.3	1.00	0.35
14	215	194.1	1.00	0.35
14.25	216	194.9	1.00	0.35
14.5	216	195.6	1.00	0.35
14.75	216	196.2	1.00	0.35
15	216	196.9	1.00	0.35

Table 7.1. Sub-Area 1 time series of catch (23) by country, fleet, and region.

Fleet Code	Country	Fleet(Region)	Annual Catch[1]	Years[1]	Percent of total catch (mt) by Fleet(Region) 1951-1983	1990-2007	Quarterly Resolution	Percent of Annual Fleet/region catch (mt) by quarter 1990-2007 Q1	Q2	Q3	Q4
F1	**Japan**	Offshore+Distant Water L. (R1-1)	Y	1951 – 2006	43.19%	16.80%	Y	49.51%	20.99%	9.87%	19.63%
F2	**Japan**	Offshore+Distant Water L. (R1-2)	Y	1951 – 2006	28.03%	16.67%	Y	32.01%	22.79%	9.55%	35.65%
F3	**Japan**	Offshore+Distant Water L. (R1-3)	Y	1960 – 2006	2.76%	0.74%	Y	61.73%	2.02%	7.09%	29.16%
F4	**Japan**	Offshore+Distant Water L. (R1-4)	Y	1951 – 2006	0.88%	0.63%	Y	18.86%	43.30%	27.04%	10.80%
F5	**Japan**	Offshore+Distant Water L. (R1-5)	Y	1951 – 2006	1.39%	1.59%	Y	36.44%	39.04%	13.49%	11.03%
F7[3]	**Japan**	Driftnet (R1-1)	Y	1972 – 2006	3.90%	5.33%	Y	33.94%	12.49%	22.29%	31.28%
F8	**Japan**	Driftnet (R1-2)	Y	1973 – 1993	1.14%	0.60%	Y	74.50%	23.82%	0.92%	0.75%
F12[2]	**Japan**	Other, Primarily Harpoon (R1-1)	Y	1951 – 2006	6.94%	2.28%	Y	33.41%	12.31%	22.79%	31.49%
F13	**Japan**	All Other Gears (R1-1)	Y	1951 – 2006	3.02%	8.30%	Y	38.98%	14.30%	8.75%	37.96%
F14	**Japan**	All Other Gears (R1-2)	Y	1951 – 1993	1.02%	0.20%	Y	76.61%	22.01%	0.73%	0.65%
F16[2]	**Japan**	All Other Gears (R1-4)	Y	1951 – 2006	0.80%	2.14%	Y	25.62%	31.19%	25.31%	17.88%
F19[2.3]	**Chinese Taipei**	Distant Water Longline (R1-1)	Y	1995 – 2006	0.00%	0.00%	Mirror F1	-	-	-	-
F20	**Chinese Taipei**	Distant Water Longline (R1-2)	Y	1995 – 2006	0.00%	0.13%	Mirror F2	-	-	-	-
F21	**Chinese Taipei**	Distant Water Longline (R1-3)	Y	2003 – 2006	0.00%	0.03%	Mirror F3	-	-	-	-
F22	**Chinese Taipei**	Distant Water Longline (R1-4)	Y	2001 – 2006	0.00%	0.01%	Mirror F4	-	-	-	-
F23	**Chinese Taipei**	Distant Water Longline (R1-5)	Y	2000 – 2006	0.00%	0.27%	Mirror F5	-	-	-	-
F25[3]	**Chinese Taipei**	All Other Gears (Assumed R1-4)	Y	1959 – 2006	4.54%	12.96%	Mirror F4	-	-	-	-
F26	**Korea**	Longline (R1-4)	Y	1976 – 2006	0.02%	0.22%	Mirror F4	-	-	-	-
F27	**Korea**	Longline (R1-5)	Y	1976 – 2006	0.04%	0.54%	Mirror F5	-	-	-	-
F29[3]	**US Hawaii**	Longline (Stratified by Depth)	Y	1976 – 2006	0.01%	19.28%	Y	35.37%	39.77%	11.34%	13.52%
F30	**US California**	Gillnet (R1-3)	Y	1984 – 2006	0.83%	5.34%	Assign Q4	-	-	-	100.00%
F31	**US California**	Longline (R1-3)	Y	1980 – 2006	0.00%	5.07%	Assign Q4	-	-	-	100.00%
F32[3]	**US California**	Other Gear + Unknown (R1-3)	Y	1970 – 2006	1.50%	0.86%	Assign Q4	-	-	-	100.00%

[1] First year with catch greater than 10 mt to last year with catch, adapted from Courtney and Wagatsuma (2009).
[2] Five Fleets (Regions) had total catch < 10 mt: F9 Japan Driftnet (R3), 8 mt; F10 Japan Driftnet (R4), 6 mt; F11 Japan Driftnet (R5), 1 mt; F15 Japan All Other Gears (R3), 1 mt; F17 Japan All Other Gears (R5).
[3] Five Fleets (Regions) were entirely in Sub-Area 2: F6 Japan Offshore+Distant Water L. (R6), F18 Japan All Other Gears R6, F24 Chinese Taipei Distant Water Longline (R6), F28 Korea Longline (R6), F33 Mexico All Gears.

Table 7.2. Sub-Area 2 time series of catch (5) by country and fleet[1].

Fleet Code	Country	Fleet	Annual Catch[1]	Years[2]	Percent of total catch (mt) by Fleet(Region) 1951-1983	1990-2007	Quarterly Resolution	Percent of Annual Fleet/region catch (mt) by quarter 1990-2007 Q1	Q2	Q3	Q4
F1	Japan	Offshore + Distant Water L.	y	1954 – 2006	93.48%	61.99%	Y	27.87%	19.49%	23.48%	29.15%
F2	Chinese Taipei	Distant Water Longline	y	1967 – 2006	0.50%	8.80%	Mirror F1	-	-	-	-
F3	Korea	Longline	y	1976 – 2005	0.76%	7.84%	Mirror F1	-	-	-	-
F4	Spain	Longline	y	1998 – 2006	0.00%	4.04%	Mirror F1				
F5	Mexico	All Gears	y	1980 – 2006	5.26%	17.33%	Assign Q4	-	-	-	100.00%

[1]Udated catch for Sub-Area 2 (BILL-WG 2009c) (Appendix A).
[2]First year with catch greater than 10 mt to last year with catch, adapted from (BILL-WG 2009c) (Appendix A).

Table 8.1. Sub-Area 1 time series of length frequency (9) by country, fleet, and region.

Fleet Code	Country	Fleet(Region)	Annual Length[1]	Years[2]	Quarterly Resolution	Length Selectivity
F1	**Japan**	Offshore+Distant Water L. (R1-1)	Y	1970 – 2006	Y	Dome
F2	**Japan**	Offshore+Distant Water L. (R1-2)	Y	1970 – 1972, 1974 – 2006	Y	Logistic
F3	**Japan**	Offshore+Distant Water L. (R1-3)	Y	1987, 1992, 2005	Assign Q1	Logistic
F4	**Japan**	Offshore+Distant Water L. (R1-4)	Y	1976 – 1979, 1981, 1983 – 2003, 2005, 2006	Y	Logistic
F5	**Japan**	Offshore+Distant Water L. (R1-5)	Y	1974, 1978, 1983 – 1997, 1999 – 2002, 2006	Assign Q2	Logistic
F7	**Japan**	Driftnet (R1-1)	Y	2004 – 2006	Assign Q1	Logistic
F8	**Japan**	Driftnet (R1-2)	N	-	Mirror F7	Mirror F7
F12	**Japan**	Other, Primarily Harpoon (R1-1)	Y	2006	Assign Q1	Modified Dome
F13	**Japan**	All Other Gears (R1-1)	N	-	Mirror F1	Mirror F1
F14	**Japan**	All Other Gears (R1-2)	N	-	Mirror F2	Mirror F2
F16	**Japan**	All Other Gears (R1-4)	N	-	Mirror F3	Mirror F3
F19	**Chinese Taipei**	Distant Water Longline (R1-1)	N	-	Mirror F1	Mirror F1
F20	**Chinese Taipei**	Distant Water Longline (R1-2)	N	-	Mirror F2	Mirror F2
F21	**Chinese Taipei**	Distant Water Longline (R1-3)	N	-	Mirror F3	Mirror F3
F22	**Chinese Taipei**	Distant Water Longline (R1-4)	N	-	Mirror F4	Mirror F4
F23	**Chinese Taipei**	Distant Water Longline (R1-5)	N	-	Mirror F5	Mirror F5
F25	**Chinese Taipei**	All Other Gears (Assume R1-4)	N	-	Mirror F4	Mirror F4
F26	**Korea**	Longline (R1-4)	N	-	Mirror F4	Mirror F4
F27	**Korea**	Longline (R1-5)	N	-	Mirror F5	Mirror F5
F29	**US Hawaii**	Longline (Stratified by Depth)	Y	1994 – 2001, 2004 – 2006	Y	Logistic
F30	**US California**	Gillnet (R1-3)	Y	1981 – 2006	Y	Logistic
F31	**US California**	Longline (R1-3)	N	-	Mirror F30	Mirror F30
F32	**US California**	Other Gear+Unknown (R1-3)	N	-	Mirror F30	Mirror F30

[1] Courtney and Fletcher (2009)

[2] Years with annual or quarterly length frequency sample size greater than 100 fish were included in the assessment.

Table 8.2. Sub-Area 2 time series of length frequency (1) by country and fleet.

Fleet Code	Country	Fleet	Annual Length[1]	Years[2]	Quarterly Resolution	Length Selectivity
F1	Japan	Offshore + Distant Water	Y	1970 – 1980, 1984, 1986 – 2006	Y	Logistic
F2	Chinese Taipei	Distant Water Longline	N	-	Mirror F1	Mirror F1
F3	Korea	Longline	N	-	Mirror F1	Mirror F1
F4	Spain	Longline	N	-	Mirror F1	Mirror F1
F5	Mexico	All Gears	N	-	Mirror F1	Mirror F1

[1] Courtney and Fletcher (2009)

[2] Years with annual or quarterly length frequency sample size greater than 100 fish.

Table 9.1. Sub-Area 1 time series of CPUE (3) by country and fleet.

Survey Code	Country	Fleet	Annual CPUE[1]	Years	Quarterly Resolution	Length Selectivity
S1	Japan	Offshore + Distant Water (Sub-Area 1)	Y	1952 – 2006	Assign Q1	Mirror F1
S8[2]	Chinese Taipei	Distant Water (Sub-Area 1)	Y	1995 – 2006	Assign Q2	Mirror F5
S15[2]	US	Hawaii Longline Shallow-Set	Y	1995 – 2000, 2004 - 2006	Assign Q2	Mirror F29

[1] Courtney and Wagatsuma (2009, Table 4)

[2] Several exploratory CPUE time series were examined but not fit in the likelihood.

Table 9.2. Sub-Area 2 time series of CPUE (2) by country and fleet.

Survey Code	Country	Fleet	Annual CPUE[1]	Years	Quarterly Resolution	Length Selectivity
S1	Japan	Offshore + Distant Water (Sub-Area 2)	Y	1955 – 2006	Assign Q4	Mirror F1
S2	Chinese Taipei	Distant Water (Sub-Area 2)	Y	1995 – 2006	Assign Q4	Mirror F1

[1] Courtney and Wagatsuma (2009, Table 4)

Table 10. Base case models for Sub-Area 1 and Sub-Area 2 under a two-stock scenario resulting from ISC BILLWG review of a single stock scenario (BILLWG 2009b) and a review of swordfish spawning in the North Pacific based on larval occurrence (Appendix B).

Model Component	Sub-Area 1	Sub-Area 2
Nat. Mort. (M)	Linked to life history (Central North Pacific)	
Steepness (h)	0.9	
sigma_r	Iteratively re-weighted once from 0.6	
Sexual Dimorphism	Sex-combined	
Spawning	Assign Q2 (April, May, June)	
Effective Sample Size for CPUE	Iteratively re-weighted once from input standard error of GLMs	Input standard error of GLMs
Initial Equilibrium Catch	Assumed initial catch = 10,512 mt (average catch from Japan Offshore + Distant Water Longline R1-1 and R1-2 during the years 1951 – 1955)	Assumed to be unfished prior to 1955
Catch	Sub-Area time series of catch regionally stratified by country and fleet (Regions 1-1 to 1-5)	Sub-Area time series of catch for one region by country and fleet (Region 2-1)
CPUE	Sub-Area wide indices (3) by country and fleet (S1, S8, S15)	Sub-Area area wide indices (2) by country and fleet (S1 and S2)
Length	Sub-Area time series of length frequency regionally stratified by country and fleet (Regions 1-1 to 1-5)	Sub-Area time series of length frequency for one region (Region 2-1) and one fleet

Table 11.1. Sub-Area 1 time blocks for length based selectivity.

Country	Fleet(Region)	Component	Block 1	Block 2	Block 3
Japan[1]	Offshore + Distant Water (F1,F2, F4, F5)	Length Selectivity	1951 – 1983	1984 – 1993	1994 – 2006
US Hawaii[2]	Longline Shallow-Set (F29)	Length Selectivity	1995 – 2003	2004 – 2006	
US California[3]	Gillnet (F30)	Length Selectivity	1980 – 1999	2000 – 2006	

[1] Ishimura et al. 2008, Okamoto and Bayliff (2003)
[2] Ito and Childers 2008.
[3] Piner and Betcher 2009

Table 11.2. Sub-Area 2 time blocks for length based selectivity.

Country	Fleet(Region)	Component	Block 1	Block 2	Block 3
Japan[1]	Offshore + Distant Water (F1)	Length Selectivity	1955 – 1983	1984 – 1993	1994 – 2006

[1] Ishimura et al. 2008, Okamoto and Bayliff (2003)

Table 12.1. Sub-Area 1 Stock Synthesis model estimates of effective sample size and the variance adjustments applied to each model.

Likelihood Component			N	Model Estimate (R.M.S.E)	Input SE	+Var Adj Sub-Area1
Sigma r			36	0.429707	0.6	-0.170293

CPUE	Country	Fleet	N	Model Estimate (R.M.S.E)	Mean Input SE	+Var Adj Sub-Area1
S1	**Japan**	Offshore + Distant Water L. (All Regions)	55	0.16	0.14	0.02
S8	**Chinese Taipei**	Distant Water Longline (All Regions)	12	0.45	0.46	-0.01
S15	**US Hawaii**	Longline Shallow-Set	9	0.25	0.15	0.10

Length Frequency	Country	Fleet (Region)	N	Model Estimate Mean Eff. n	Mean Input Sqrt(n)	*n_Adj Sub-Area1
F1	**Japan**	Offshore + Distant Water (R1-1)	133	226.1	61.8	1
F2	**Japan**	Offshore + Distant Water (R1-2)	115	267.8	57.3	1
F3	**Japan**	Offshore + Distant Water (R1-3)	3	94.3	13.7	1
F4	**Japan**	Offshore + Distant Water (R1-4)	78	120.6	16.0	1
F5	**Japan**	Offshore + Distant Water (R1-5)	21	134.1	17.5	1
F7	**Japan**	Driftnet (R1-1)	3	370.8	36.9	1
F12	**Japan**	Other, Primarily Harpoon (R1-1)	1	189.1	22.3	1
F29	**US Hawaii**	Longline (Stratified by Depth)	33	202.6	31.9	1
F30	**US California**	Gillnet (R1-3)	48	152.8	25.6	1

Table 12.2. Sub-Area 2 Stock Synthesis model estimates of effective sample size and the variance adjustments applied to each model.

Likelihood Component			N	Model Estimate (R.M.S.E)	Input SE	+Var Adj Sub-Area 2
Sigma r			36	0.510413	0.6	-0.089587

CPUE	Country	Fleet	N	Model Estimate (R.M.S.E)	Mean Input SE	+Var Adj Sub-Area 2
S1	**Japan**	Offshore + Distant Water L.	52	0.33	0.13	0.00
S2	**Chinese Taipei**	Distant Water Longline	12	0.30	0.44	0.00

Length Frequency	Country	Fleet (Region)	N	Model Estimate Mean Eff. n	Mean Input Sqrt(n)	*n_Adj Sub-Area 2
F1	**Japan**	Offshore + Distant Water L.	111	125.6	18.5	1

Table 13.1. Sub-Area 1 Stock Synthesis (SS) estimated time-series of female spawning biomass (S), recruitment (R), total biomass (B), and age 2+ biomass (B_2+); Along with Bayesian surplus production (BSP) estimates of mean exploitable biomass (BSP Mean Biomass) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%)[1].

Year	SS S (mt)	s.e.	SS R (1,000s)	s.e.	SS B (mt)	SS B_2+ (mt)	BSP[1] MCMC 2.5%	BSP[1] Mean Biomass	BSP[1] MCMC 97.5%
Virgin	41,487	584	691	10					
1951	18,277	620	435	136	54,225	45,555	58,850	96,300	149,300
1952	17,818	598	549	176	53,839	45,287	48,170	80,600	127,700
1953	17,280	655	543	181	50,038	44,654	44,050	74,190	118,300
1954	14,737	1,001	604	211	45,258	38,524	46,060	76,910	122,600
1955	12,359	1,276	924	313	39,576	32,902	44,480	74,210	119,100
1956	9,413	1,332	930	337	35,096	27,732	42,240	70,300	112,200
1957	8,040	1,275	763	294	34,506	23,315	42,920	71,250	113,500
1958	7,947	1,249	1,083	319	36,740	25,466	47,370	77,460	122,900
1959	7,926	1,119	779	270	33,748	24,613	44,000	72,580	115,800
1960	6,893	944	676	228	34,789	21,939	44,400	72,910	115,700
1961	6,349	933	623	208	30,645	21,480	40,860	69,070	111,700
1962	5,888	822	609	207	25,009	17,163	36,610	64,750	107,700
1963	6,772	1,015	626	206	26,242	18,766	39,720	69,230	113,500
1964	8,066	1,213	523	173	28,389	21,059	41,090	70,840	115,300
1965	9,687	1,279	507	168	32,890	25,181	44,890	75,550	121,200
1966	10,200	1,250	617	186	33,557	27,173	44,010	74,130	119,200
1967	9,527	1,206	523	155	32,519	26,333	40,380	68,480	110,000
1968	9,315	1,128	357	103	31,633	24,128	37,650	64,230	103,500
1969	9,224	1,011	484	103	30,897	24,531	37,360	64,080	103,500
1970	9,801	911	426	89	30,123	25,728	39,310	66,960	107,300
1971	9,501	826	226	62	29,926	23,964	40,330	68,420	109,800
1972	9,435	744	1,036	123	29,864	24,629	41,610	70,300	113,200
1973	9,424	773	676	122	27,688	24,852	45,370	76,150	121,700
1974	9,925	805	423	86	34,233	21,456	48,700	81,300	129,000
1975	11,842	838	493	74	39,602	31,292	48,600	81,080	129,100
1976	12,833	858	487	69	39,303	34,093	48,270	81,020	129,600
1977	12,289	842	533	71	37,014	30,943	44,640	75,690	121,500
1978	11,223	784	609	79	34,529	28,546	43,240	73,110	117,100
1979	9,581	717	626	81	31,614	25,077	43,970	74,990	120,600
1980	9,626	675	622	78	31,646	24,193	47,770	81,050	130,300
1981	10,058	657	502	70	34,163	26,440	49,360	83,100	133,400
1982	11,107	658	913	77	36,191	28,516	50,930	85,640	137,600
1983	11,595	654	1,044	79	37,090	30,871	57,410	96,370	154,400
1984	11,766	648	505	60	40,393	29,139	58,710	99,360	159,800
1985	12,863	665	707	53	46,104	33,374	64,140	109,400	177,200
1986	13,768	693	533	49	44,337	38,185	63,330	109,700	178,900
1987	13,880	710	833	57	44,260	35,618	66,050	113,400	185,200
1988	13,326	708	667	56	41,638	35,105	63,550	109,100	178,200
1989	13,393	698	483	49	43,290	33,048	59,140	101,000	163,900
1990	13,910	678	823	54	44,895	36,682	60,230	101,900	164,500
1991	14,464	642	884	60	43,599	37,620	57,820	97,430	156,600
1992	13,582	581	647	56	44,688	34,568	57,900	96,930	155,400
1993	12,449	528	609	52	43,878	33,119	52,160	88,420	142,800
1994	11,832	526	670	54	40,110	32,297	42,510	73,310	119,300
1995	12,035	536	676	50	38,784	31,310	36,260	61,920	100,500
1996	11,796	527	242	36	38,851	30,624	34,510	58,290	93,940
1997	11,850	512	987	52	39,788	31,486	31,980	53,500	86,040
1998	11,432	495	825	59	34,748	31,729	31,650	53,260	85,370
1999	10,397	476	393	48	36,851	24,727	35,530	59,370	94,850
2000	10,748	493	492	50	39,628	29,526	40,330	67,080	106,800
2001	11,629	553	566	56	36,630	31,809	42,460	72,060	116,300
2002	11,824	604	619	70	35,716	29,637	43,170	72,620	116,400
2003	11,448	633	788	85	35,224	28,241	40,480	68,050	108,600
2004	10,857	678	473	68	35,358	27,730	40,650	68,040	108,500
2005	11,084	816	356	75	38,444	28,769	41,960	69,980	111,300
2006	11,796	1,100	589	253	38,239	32,424	44,800	74,910	119,500

[1] (BILLWG 2009b).

Table 13.2. Sub-Area 2 Stock Synthesis (SS) estimated time-series of female spawning biomass (S), recruitment (R), total biomass (B), and age 2+ biomass (B_2+); Along with Bayesian surplus production (BSP) estimates of mean exploitable biomass (BSP Mean Biomass) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%)[1].

Year	SS S (mt)	s.e.	SS R (1,000s)	s.e.	SS B (mt)	SS B_2+ (mt)	BSP[1] MCMC 2.5%	BSP[1] Mean Biomass	BSP[1] MCMC 97.5%
Virgin	48,774	10,104	813	168					
1955	48,773	10,104	462	167	119,306	109,113	8,901	24,700	47,700
1956	48,756	10,101	423	152	119,276	109,102	9,866	23,740	45,310
1957	48,243	9,997	429	153	114,881	109,094	15,590	34,780	62,770
1958	46,241	9,613	526	192	107,855	102,553	14,570	31,900	58,420
1959	43,072	8,991	751	289	100,002	94,612	12,300	27,660	51,810
1960	39,694	8,297	1,081	432	93,631	87,025	14,430	31,690	58,630
1961	37,281	7,791	1,059	413	91,468	82,039	19,850	42,220	76,220
1962	36,859	7,799	835	323	95,580	82,033	24,350	51,330	91,810
1963	38,809	8,503	698	265	102,540	89,289	27,920	58,140	103,600
1964	41,450	9,500	716	271	106,979	96,546	27,860	58,880	106,300
1965	43,670	10,215	857	332	108,327	99,593	26,230	56,200	102,500
1966	44,470	10,439	1,141	434	108,847	99,874	27,570	58,520	105,300
1967	44,330	10,378	1,342	481	109,292	98,546	27,300	58,390	106,400
1968	44,850	10,405	931	328	114,167	99,868	29,390	62,490	113,000
1969	46,649	10,838	1,219	342	122,943	106,171	34,220	71,070	127,800
1970	47,791	11,572	703	280	123,557	111,951	33,300	72,100	131,400
1971	50,468	12,170	720	345	128,921	113,710	29,080	64,070	118,000
1972	52,854	12,499	938	490	130,194	121,395	29,120	62,850	115,100
1973	52,809	12,456	598	396	127,838	118,812	31,630	67,330	122,200
1974	51,267	12,219	1,234	516	125,063	113,353	31,690	67,420	122,000
1975	49,859	11,976	862	432	120,327	112,806	31,570	66,960	120,700
1976	48,460	11,841	846	328	121,916	106,494	30,780	65,320	117,400
1977	48,156	11,865	401	199	121,413	110,632	31,060	65,420	117,700
1978	47,995	11,886	633	276	120,009	109,458	27,220	57,980	105,600
1979	47,231	11,691	444	224	112,939	107,911	24,860	53,360	96,760
1980	44,730	11,094	430	208	106,811	98,908	24,170	51,310	92,870
1981	41,112	10,276	361	173	97,769	92,227	21,330	46,000	83,710
1982	36,963	9,396	380	185	87,741	82,393	19,050	41,300	75,730
1983	33,087	8,545	873	401	78,635	74,132	17,800	39,180	71,960
1984	29,833	7,764	1,491	465	71,254	66,488	14,400	32,440	61,170
1985	28,114	7,258	456	219	72,127	61,162	16,250	35,530	65,670
1986	29,433	7,401	385	175	84,382	65,759	20,330	43,090	78,160
1987	33,044	8,003	568	232	87,765	82,069	22,820	47,820	85,990
1988	34,711	8,378	709	268	85,365	80,542	20,690	44,190	80,010
1989	33,703	8,253	641	239	81,733	74,618	20,410	43,430	78,910
1990	31,933	7,893	624	229	80,414	71,548	22,080	45,610	81,950
1991	29,707	7,637	637	240	76,327	68,335	19,620	41,410	75,360
1992	28,720	7,492	702	239	74,450	66,651	19,750	41,280	74,590
1993	27,535	7,398	626	228	71,583	63,632	18,830	40,470	74,410
1994	27,427	7,396	903	294	71,735	62,969	18,480	39,680	72,830
1995	27,744	7,488	953	333	71,989	64,178	19,720	42,090	75,850
1996	28,635	7,644	1,003	344	76,111	64,844	24,830	51,860	93,140
1997	30,417	7,961	695	324	82,190	70,299	30,670	62,380	109,900
1998	31,816	8,443	1,869	557	86,690	74,266	29,610	61,470	109,700
1999	33,057	9,002	1,647	532	86,160	77,500	26,710	57,850	106,300
2000	36,245	9,704	617	298	102,623	79,322	34,840	73,310	131,400
2001	41,284	11,003	825	298	119,012	98,578	39,990	85,020	152,200
2002	46,494	12,453	896	315	121,429	113,733	36,850	80,230	144,500
2003	48,411	13,208	797	317	120,317	110,035	35,600	76,100	137,300
2004	47,286	13,220	939	331	117,644	106,480	33,130	71,030	128,800
2005	45,787	12,935	347	185	113,696	103,741	29,880	64,430	117,200
2006	45,084	12,672	712	393	113,143	101,437	32,950	69,540	125,300

[1](Brodziak 2010).

Table 14.1 Sub-Area 1 Stock Synthesis (SS) estimated time series of annual fishing mortality (F) (the sum of quarterly fishing mortality for all fleets), and total exploitation (Catch mt)/(B_2+ mt); Along with Bayesian surplus production (BSP) estimates of mean exploitable biomass harvest rates (BSP Mean Harvest Rate) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%)[1].

Year	SS F	s.e.	SS C/B_2+	BSP[1] MCMC 2.5%	BSP[1] Mean Harvest Rate	BSP[1] MCMC 97.5%
1951	0.69	0.105	0.26	0.078	0.13	0.198
1952	0.55	0.070	0.26	0.092	0.15	0.243
1953	0.47	0.042	0.28	0.105	0.18	0.282
1954	0.52	0.044	0.35	0.111	0.19	0.295
1955	0.64	0.069	0.43	0.118	0.20	0.317
1956	0.85	0.116	0.56	0.138	0.23	0.367
1957	0.98	0.152	0.65	0.134	0.23	0.353
1958	1.38	0.221	0.77	0.160	0.27	0.415
1959	1.35	0.172	0.76	0.162	0.27	0.425
1960	1.95	0.173	1.00	0.190	0.32	0.494
1961	2.39	0.168	0.98	0.189	0.33	0.516
1962	1.88	0.121	0.69	0.111	0.20	0.325
1963	1.30	0.097	0.55	0.091	0.16	0.259
1964	1.87	0.113	0.37	0.068	0.12	0.190
1965	1.56	0.203	0.42	0.087	0.15	0.235
1966	1.33	0.186	0.41	0.094	0.16	0.254
1967	0.99	0.131	0.45	0.107	0.18	0.291
1968	1.41	0.224	0.46	0.108	0.19	0.297
1969	1.12	0.186	0.35	0.084	0.15	0.233
1970	1.23	0.195	0.34	0.081	0.14	0.222
1971	0.92	0.127	0.32	0.071	0.12	0.193
1972	0.98	0.138	0.29	0.064	0.11	0.175
1973	0.84	0.104	0.30	0.061	0.10	0.163
1974	0.67	0.078	0.39	0.064	0.11	0.170
1975	0.80	0.110	0.34	0.083	0.14	0.222
1976	1.04	0.150	0.35	0.091	0.16	0.244
1977	0.65	0.081	0.36	0.091	0.16	0.246
1978	0.77	0.093	0.43	0.105	0.18	0.285
1979	0.69	0.067	0.42	0.087	0.15	0.238
1980	0.75	0.090	0.37	0.069	0.12	0.188
1981	0.79	0.095	0.37	0.074	0.13	0.199
1982	0.82	0.092	0.33	0.068	0.12	0.185
1983	0.83	0.082	0.37	0.074	0.13	0.198
1984	0.92	0.090	0.43	0.079	0.14	0.216
1985	0.80	0.066	0.45	0.085	0.15	0.234
1986	0.72	0.065	0.34	0.072	0.13	0.203
1987	0.87	0.092	0.37	0.070	0.12	0.198
1988	0.76	0.076	0.33	0.065	0.11	0.182
1989	0.66	0.062	0.33	0.067	0.12	0.185
1990	0.49	0.037	0.30	0.068	0.12	0.185
1991	0.49	0.029	0.31	0.074	0.13	0.200
1992	0.77	0.048	0.47	0.104	0.18	0.279
1993	0.81	0.047	0.53	0.122	0.21	0.335
1994	0.79	0.054	0.43	0.115	0.20	0.323
1995	0.74	0.055	0.40	0.124	0.22	0.344
1996	0.77	0.063	0.38	0.125	0.22	0.341
1997	0.67	0.044	0.40	0.146	0.25	0.392
1998	0.74	0.053	0.39	0.144	0.25	0.388
1999	0.90	0.067	0.53	0.138	0.24	0.370
2000	0.88	0.074	0.49	0.135	0.23	0.357
2001	0.54	0.046	0.33	0.090	0.15	0.245
2002	0.55	0.052	0.34	0.088	0.15	0.237
2003	0.59	0.055	0.38	0.099	0.17	0.264
2004	0.57	0.054	0.37	0.096	0.16	0.256
2005	0.58	0.058	0.38	0.098	0.17	0.260
2006	0.59	0.066	0.36	0.083	0.14	0.222

[1] (BILLWG 2009b).

Table 14.2 Sub-Area 2 Stock Synthesis (SS) estimated time series of annual fishing mortality (F) (the sum of quarterly fishing mortality for all fleets), and total exploitation (Catch mt)/(B_2+ mt); Along with Bayesian surplus production (BSP) estimates of mean exploitable biomass harvest rates (BSP Mean Harvest Rate) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%)[1].

Year	SS F	s.e.	SS C/B_2+	BSP[1] MCMC 2.5%	BSP[1] Mean Harvest Rate	BSP[1] MCMC 97.5%
1955	0.00	0.000	0.00	0.000	0.00	0.001
1956	0.00	0.000	0.00	0.000	0.00	0.001
1957	0.00	0.000	0.00	0.003	0.01	0.011
1958	0.00	0.000	0.00	0.002	0.00	0.010
1959	0.00	0.000	0.00	0.002	0.00	0.008
1960	0.00	0.000	0.00	0.002	0.00	0.010
1961	0.01	0.002	0.01	0.008	0.02	0.033
1962	0.01	0.003	0.01	0.012	0.02	0.044
1963	0.03	0.006	0.02	0.022	0.04	0.080
1964	0.03	0.007	0.02	0.022	0.05	0.085
1965	0.01	0.004	0.01	0.013	0.03	0.050
1966	0.02	0.005	0.02	0.020	0.04	0.075
1967	0.02	0.004	0.01	0.014	0.03	0.054
1968	0.02	0.005	0.02	0.017	0.03	0.064
1969	0.07	0.018	0.07	0.057	0.11	0.213
1970	0.04	0.011	0.04	0.032	0.07	0.128
1971	0.02	0.004	0.02	0.015	0.03	0.062
1972	0.02	0.005	0.02	0.019	0.04	0.075
1973	0.03	0.008	0.03	0.030	0.06	0.115
1974	0.02	0.005	0.02	0.017	0.03	0.065
1975	0.02	0.006	0.02	0.020	0.04	0.075
1976	0.03	0.008	0.03	0.028	0.06	0.107
1977	0.04	0.010	0.03	0.032	0.07	0.123
1978	0.04	0.009	0.03	0.035	0.07	0.134
1979	0.03	0.008	0.03	0.029	0.06	0.113
1980	0.04	0.011	0.04	0.042	0.08	0.160
1981	0.06	0.015	0.05	0.056	0.12	0.221
1982	0.05	0.013	0.04	0.048	0.10	0.191
1983	0.04	0.012	0.04	0.040	0.08	0.162
1984	0.03	0.008	0.03	0.030	0.06	0.127
1985	0.03	0.009	0.03	0.029	0.06	0.119
1986	0.06	0.015	0.06	0.047	0.10	0.180
1987	0.07	0.017	0.06	0.054	0.11	0.203
1988	0.07	0.018	0.06	0.062	0.13	0.238
1989	0.06	0.015	0.05	0.051	0.10	0.197
1990	0.12	0.030	0.10	0.091	0.18	0.337
1991	0.10	0.025	0.08	0.077	0.16	0.294
1992	0.13	0.035	0.11	0.101	0.20	0.380
1993	0.10	0.028	0.09	0.076	0.16	0.302
1994	0.08	0.022	0.08	0.070	0.15	0.276
1995	0.07	0.019	0.07	0.057	0.12	0.220
1996	0.07	0.017	0.07	0.046	0.09	0.173
1997	0.10	0.027	0.10	0.067	0.13	0.238
1998	0.12	0.033	0.12	0.082	0.16	0.304
1999	0.06	0.015	0.06	0.041	0.09	0.164
2000	0.08	0.021	0.09	0.054	0.11	0.204
2001	0.09	0.024	0.09	0.059	0.12	0.225
2002	0.07	0.020	0.07	0.055	0.11	0.215
2003	0.07	0.019	0.07	0.053	0.11	0.206
2004	0.07	0.019	0.06	0.052	0.11	0.204
2005	0.04	0.013	0.04	0.038	0.08	0.148
2006	0.04	0.011	0.04	0.031	0.06	0.119

[1](Brodziak 2010).

Table 15.1. Sub-Area 1 Stock Synthesis model results for individual likelihood component fits to CPUE data (Total, S1, S8, and S15), total recruitment, and total objective function, along with the total number of estimated parameters.

Model	Total (S)	S1	S8	S15	Total Recruitment	Total Obj Fun	# Parameters
Sub-Area 1 (This Assessment)	-89.5	-76.5	-5.7	-7.3	-19.7	1,670.0	119
Sub-Area 1 (Preliminary Assessment)[1]	-58.1	-48.1	-5.6	-4.4	-19	1,689.2	107
Relative Change in Likelihood Units (This Assessment - Preliminary Assessment[1])	-31.4	-28.4	-0.1	-2.9	-0.7	-19.2	12

[1](Courtney and Piner 2009c).

Table 15.2. Sub-Area 2 Stock Synthesis model results for individual likelihood component fits to CPUE data (Total, S1 and S2), total recruitment, and total objective function, along with the total number of estimated parameters.

Model	Total (S)	S1	S2	Total Recruitment	Total Obj Fun	# Parameters
Sub-Area 2 (This Assessment)	-56.7	-46.0	-10.7	-11.7	325.2	69
Sub-Area 2 (Preliminary Assessment)[1]	125.6	-31.6	157.2	-12.7	505.1	67
Relative Change in Likelihood Units (This Assessment - Preliminary Assessment[1])	-182.3	-14.4	-167.9	1.0	-179.9	2.0

[1](Courtney and Piner 2009c).

Table 16.1. Sub-Area 1 Stock Synthesis model results for individual likelihood component fits to length data (Total, F1, F2, F3, F4, F5, F7, F12, F29, and F30).

Model	Total	F1	F2	F3	F4	F5	F7	F12	F29	F30
Sub-Area 1 (This Assessment)	1,778.9	715.4	491.3	52.3	175.3	52.0	6.2	2.6	106.6	177.2
Sub-Area 1 (Preliminary Assessment)[1]	1,764.2	725.4	507.2	6.4	170.8	52.8	5.6	1.4	108.2	186.5
Relative Change in Likelihood Units (This Assessment - Preliminary Assessment[1])	14.7	-10.0	-15.9	45.9	4.5	-0.8	0.6	1.2	-1.6	-9.3

[1](Courtney and Piner 2009c).

Table 16.2. Sub-Area 2 Stock Synthesis model results for individual likelihood component fits to length data (Total and F1).

Model	Total	F1
Sub-Area 2 (This Assessment)	393.6	393.6
Sub-Area 2 (Preliminary Assessment)[1]	392.2	392.2
Relative Change in Likelihood Units (This Assessment - Preliminary Assessment[1])	1.4	1.4

[1](Courtney and Piner 2009c).

Table 17.1. Sub-Area 1 Stock Synthesis estimates of unfished female spawning biomass (S_0), total biomass in 1951 (B_1951) and the ratios of ending year to female spawning biomass at MSY (S_2006/S_MSY), unfished female spawning biomass (S_2006/S_0), unfished recruitment (R_2006/R_0), total biomass in 1951 (B_2006/B_1951), and age 2+ biomass in 1951 (B_2+ 2006/B_2+ 1951).

Model	S_0 Unfished (mt)	B_1951 (mt)	S_2006/ S_MSY	S_2006/ S_0	R_2006/ R_0	B_2006/ B_1951	(B_2+ 2006)/ (B_2+ 1951)
Sub-Area 1 (This Assessment)	41,487	54,225	**1.47**	28%	85%	71%	71%
Sub-Area 1 (Preliminary Assessment)[1]	43,230	54,585	1.47	30%	39%	65%	68%
Relative Change (This Assessment - Preliminary Assessment[1])	-1,743	-360	0.00	-0.02	0.46	0.06	0.03

[1](Courtney and Piner 2009c).

Table 17.2. Sub-Area 2 Stock Synthesis estimates of unfished female spawning biomass (S_0), total biomass in 1955 (B_1955) and the ratios of ending year to female spawning biomass at MSY (S_2006/S_MSY), unfished female spawning biomass (S_2006/S_0), unfished recruitment (R_2006/R_0), total biomass in 1955 (B_2006/B_1955), and age 2+ biomass in 1955 (B_2+ 2006/B_2+ 1955).

Model	S_0 Unfished (mt)	B_1955 (mt)	S_2006/ S_MSY	S_2006/ S_0	R_2006/ R_0	B_2006/ B_1955	(B_2+ 2006)/ (B_2+ 1955)
Sub-Area 2 (This Assessment)	48,774	119,306	**4.87**	92%	88%	95%	93%
Sub-Area 2 (Preliminary Assessment)[1]	17,713	41,893	2.84	54%	68%	57%	53%
Relative Change (This Assessment - Preliminary Assessment[1])	31,061	77,413	2.03	0.38	0.20	0.38	0.40

[1](Courtney and Piner 2009c).

Table 18.1. Sub-Area 1 Stock Synthesis model estimates of maximum sustainable yield (MSY), fishing mortality at MSY (F_MSY), initial fishing mortality for fleet 1 (Init_F_F1), maximum F during the years 1951 – 2006, average F during the years 1951 - 2006, average F during the years 1995 – 2006 (F_Avg (1995-2006)), and the ratio F_Avg (1995-2006) to F_MSY.

Model	MSY (mt)	F_MSY	s.e	Init_F_F1	s.e	F_Max 1951 - 12006	F_Avg 1951 - 2006	F_Avg 1995 - 2006	F_Avg (1995-2006) / F_MSY
Sub-Area 1 (This Assessment)	12,449	0.89	0.047	1.07	0.052	2.39	0.91	0.68	0.76
Sub-Area 1 (Preliminary Assessment)[1]	12,325	0.80	0.036	1.10	0.064	2.77	0.90	0.64	0.80
Relative Change (This Assessment - Preliminary Assessment[1])	124	0.09	0.011	-0.03	-0.012	-0.38	0.01	0.04	-0.04

[1](Courtney and Piner 2009c).

Table 18.2. Sub-Area 2 Stock Synthesis model estimates of maximum sustainable yield (MSY), fishing mortality at MSY (F_MSY), initial fishing mortality for fleet 1 (Init_F_F1), maximum F during the years 1955 – 2006, average F during the years 1955 - 2006, average F during the years 1995 – 2006 (F_Avg (1995-2006)), and the ratio F_Avg (1995-2006) to F_MSY.

Model	MSY (mt)	F_MSY	s.e	Init_F_F1	s.e	F_Max 1955 - 12006	F_Avg 1955 - 2006	F_Avg 1995 - 2006	F_Avg (1995-2006) / F_MSY
Sub-Area 2 (This Assessment)	13,902	0.58	0.021	0.00	NA	0.13	0.05	0.07	0.13
Sub-Area 2 (Preliminary Assessment)[1]	5,050	0.66	0.027	NA	NA	0.42	0.13	0.24	0.24
Relative Change (This Assessment - Preliminary Assessment[1])	8,852	-0.08	-0.006	NA	NA	-0.29	-0.08	-0.17	-0.11

[1](Courtney and Piner 2009c).

Figures

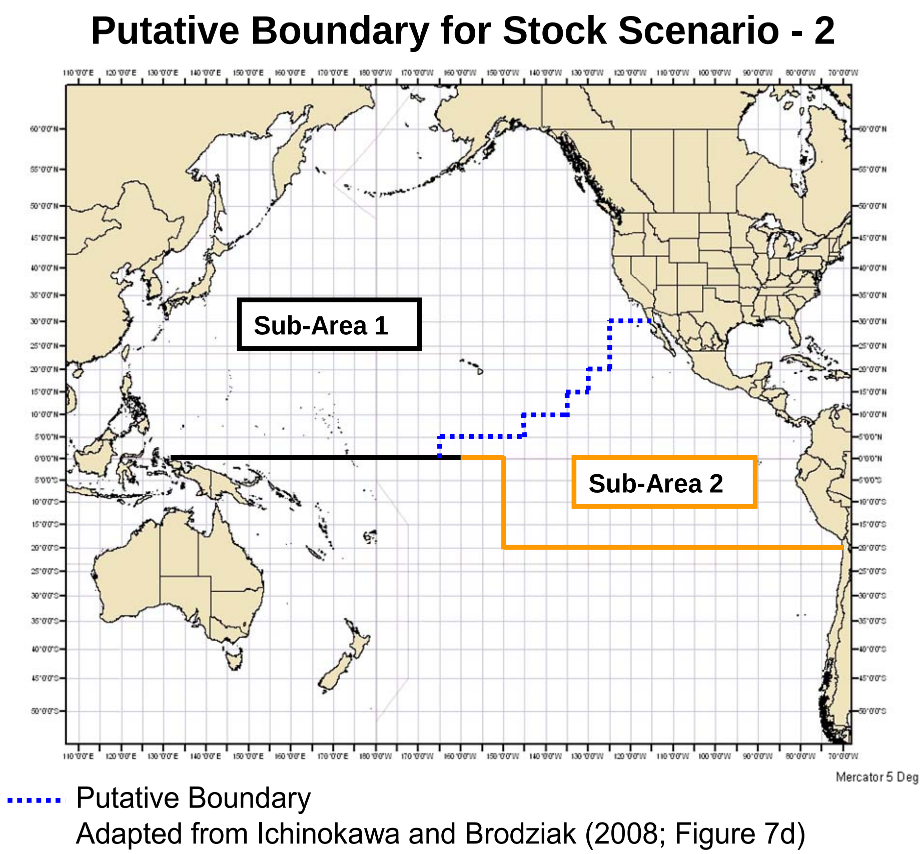

Figure 1. Stock Scenario-2, two North Pacific swordfish stocks north of the equator (BILL-WG 2008, BILL-WG 2009a, BILL-WG 2009b).

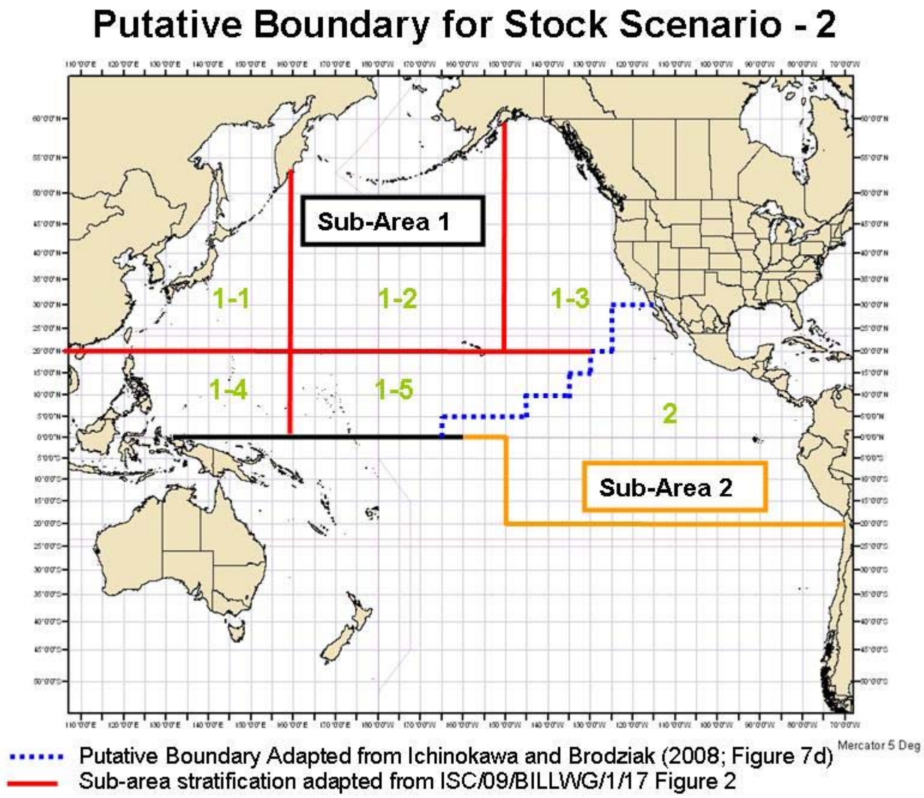

Figure 2. Regional stratification under Stock Scenario-2 (BILL-WG 2009a, BILL-WG 2009b).

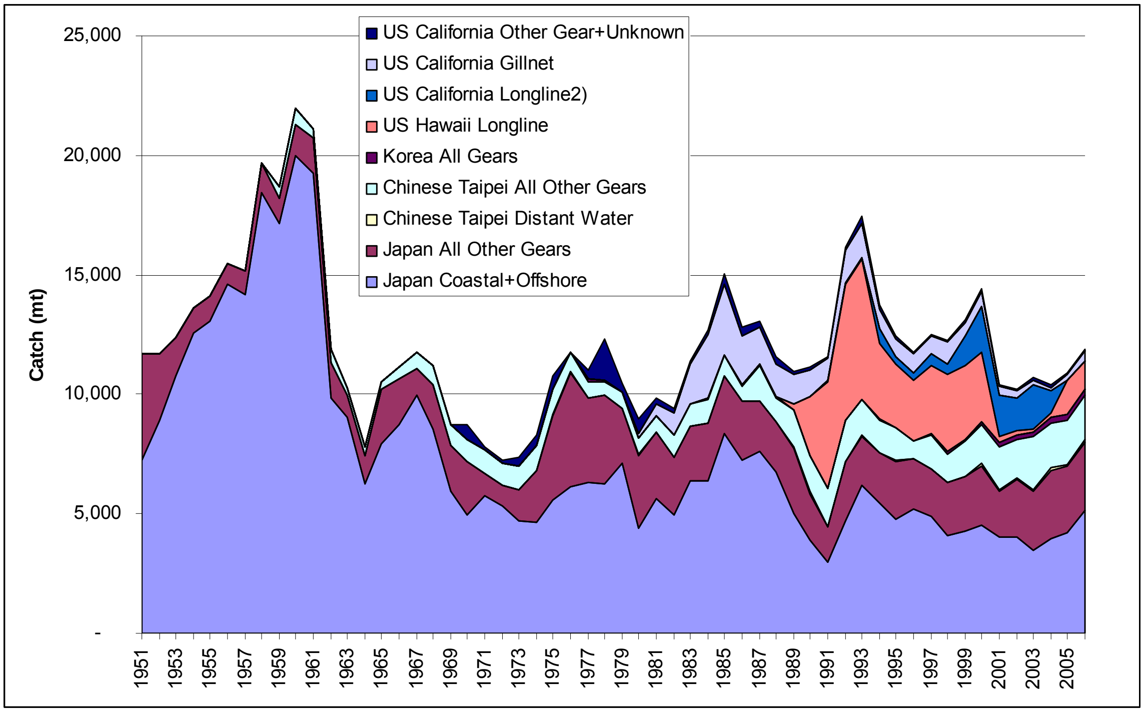

Figure 3.1. Sub-Area 1 annual catch of swordfish (mt) by fleet (Courtney and Wagatsuma 2009).

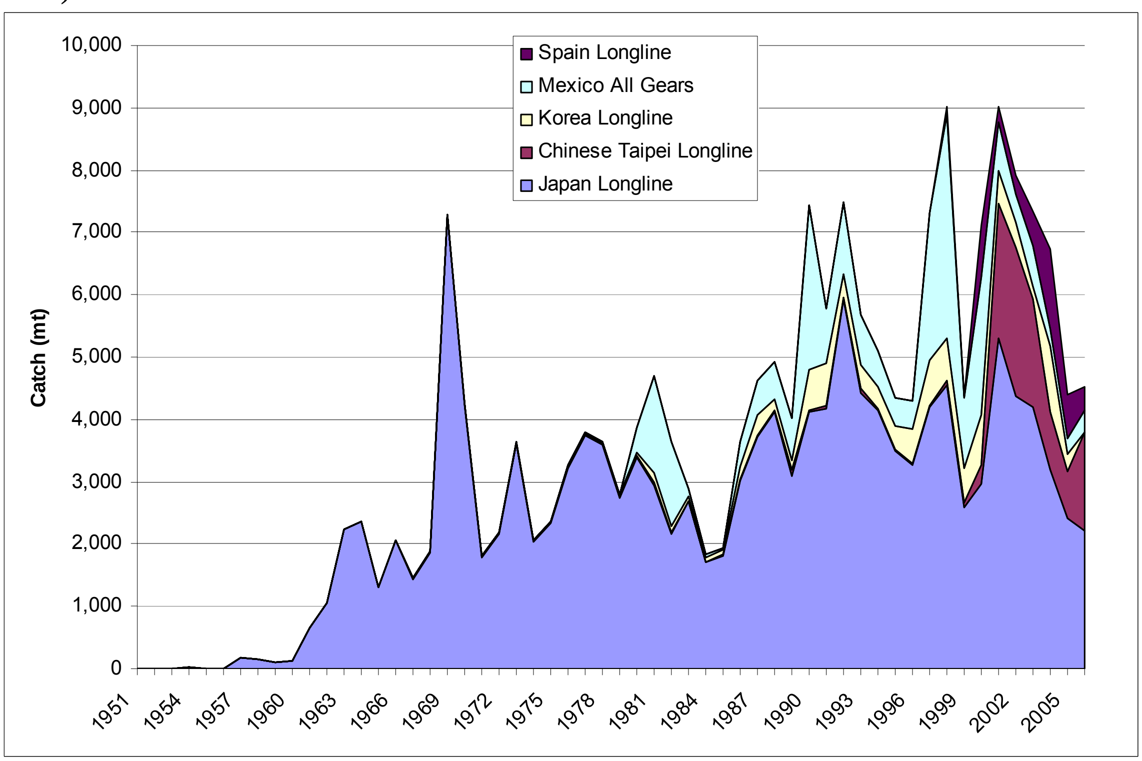

Figure 3.2. Sub-Area 2 annual catch of swordfish (mt) by fleet (BILL-WG 2009c; Appendix A).

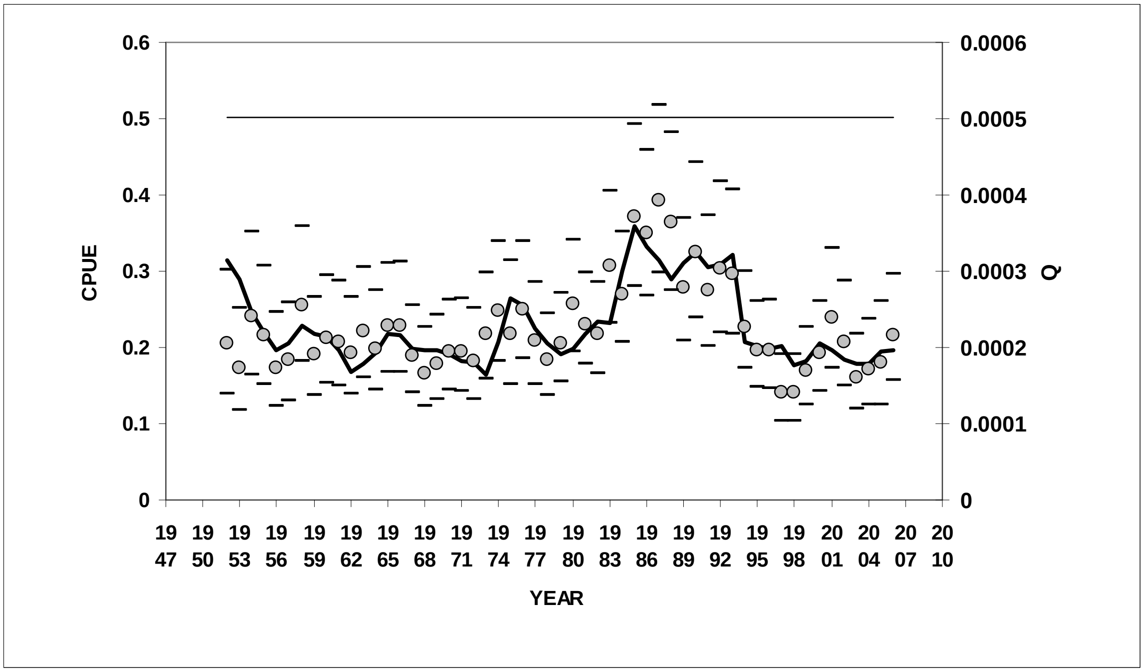

Figure 4.1. Sub-Area 1 Stock Synthesis model fit to standardized CPUE time series (S1) Japan Offshore + Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(iteratively reweighted input se), and thin line is effective q.

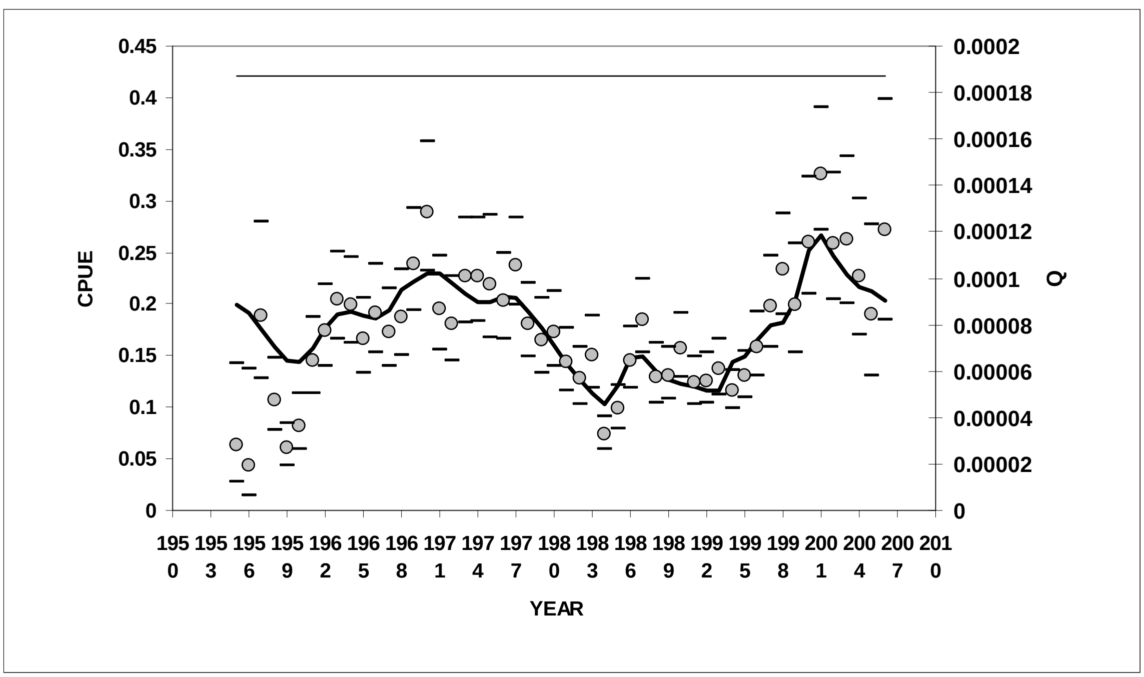

Figure 4.2. Sub-Area 2 Stock Synthesis model fit standardized CPUE time series (S1) Japan Offshore + Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(iteratively reweighted input se), and thin line is effective q.

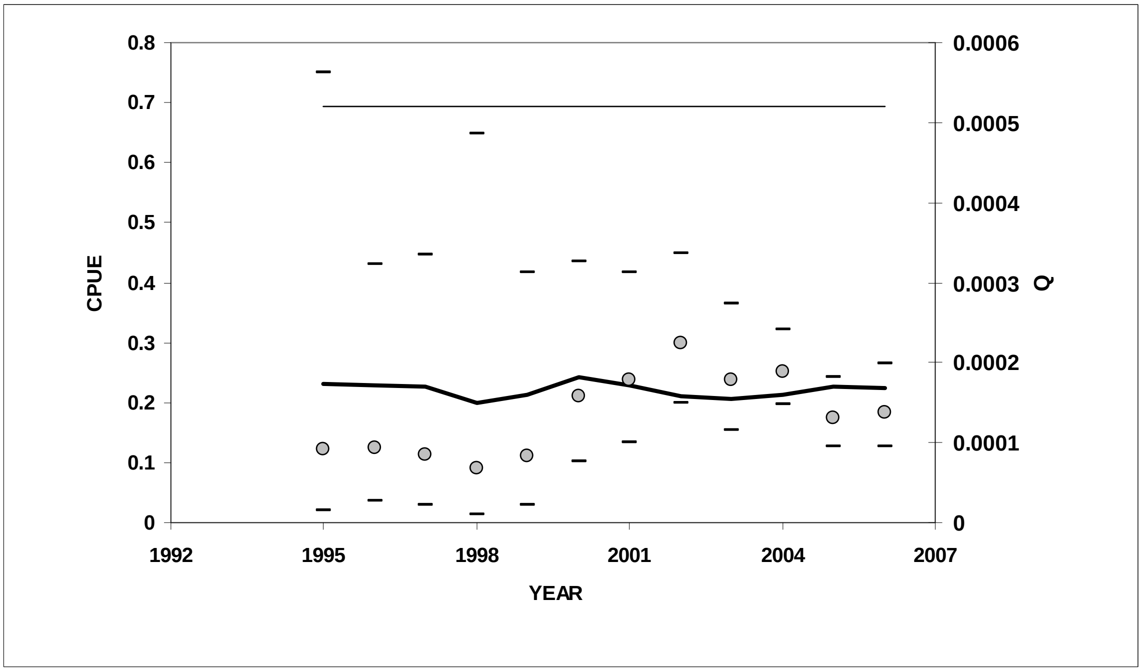

Figure 5.1. Sub-Area 1 fit to Standardized CPUE time series (S8) Chinese Taipei Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +- 2*(iteratively reweighted input se), and thin line is effective q.

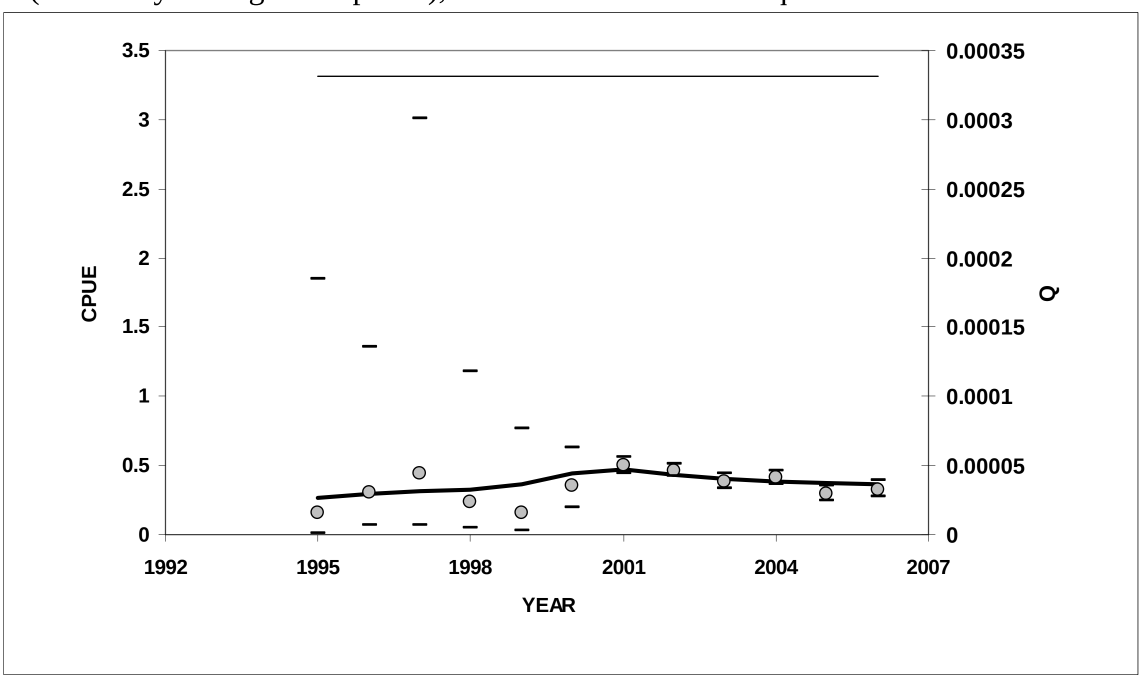

Figure 5.2. Sub-Area 2 fit to Standardized CPUE time series (S2) Chinese Taipei Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +- 2*(iteratively reweighted input se), and thin line is effective q.

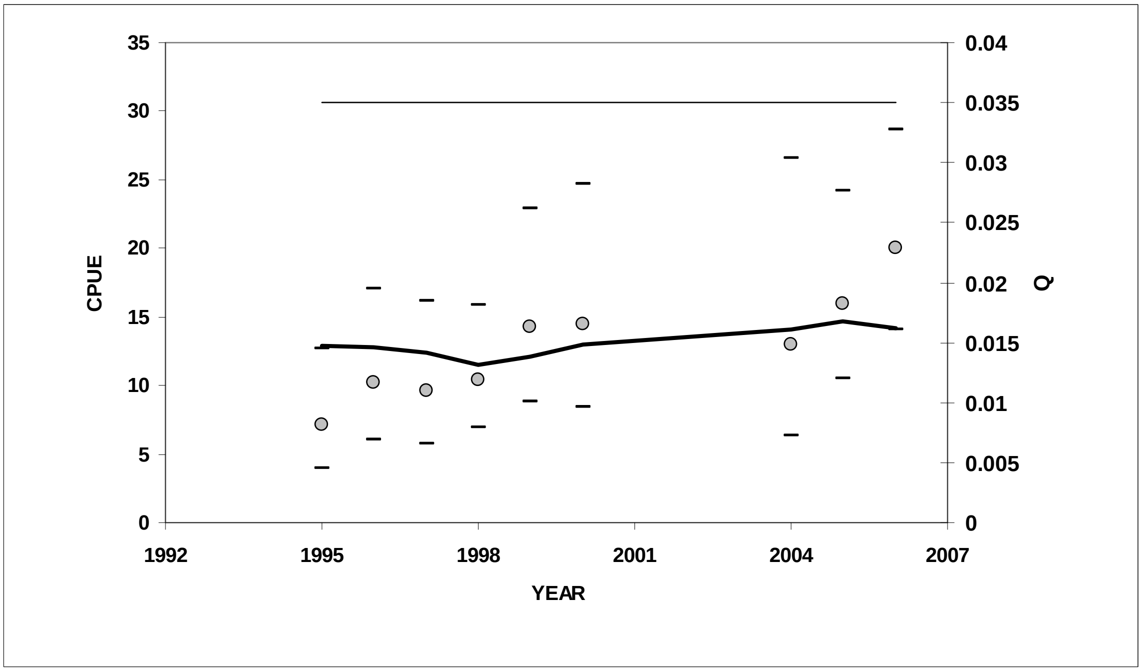

Figure 6.1. Sub-Area 1 Stock Synthesis model estimated standardized CPUE time series (S15) US Hawaii Longline Shallow-Set. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(iteratively reweighted input se), and thin line is effective q.

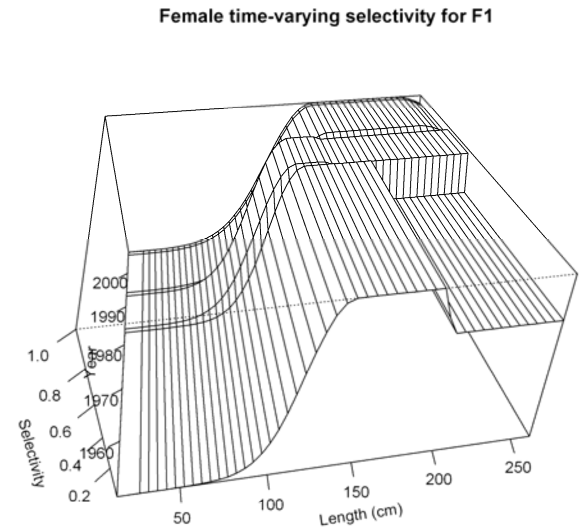

Figure 7.1. Sub-Area 1 length selectivity (F1) Japan Offshore + Distant Water Longline in Region 1-1 (Female = Male; 1951 – 1983, 1984 – 1993, 1994 – 2006).

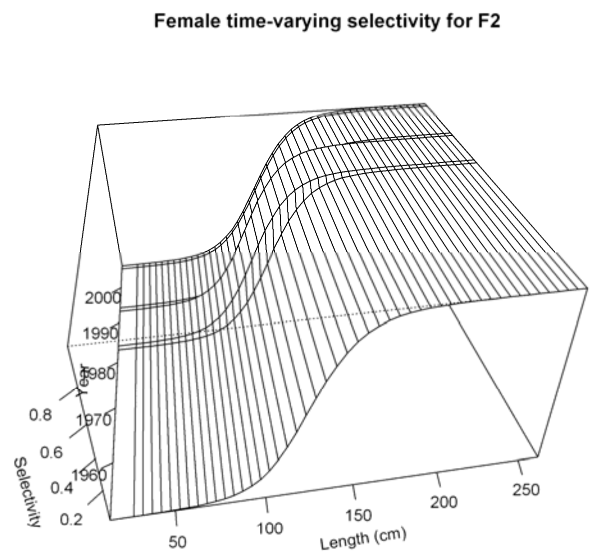

Figure 7.2. Sub-Area 1 length selectivity (F2) Japan Offshore + Distant Water Longline in Region 1-2 (Female = Male; 1951 – 1983, 1984 – 1993, 1994 – 2006).

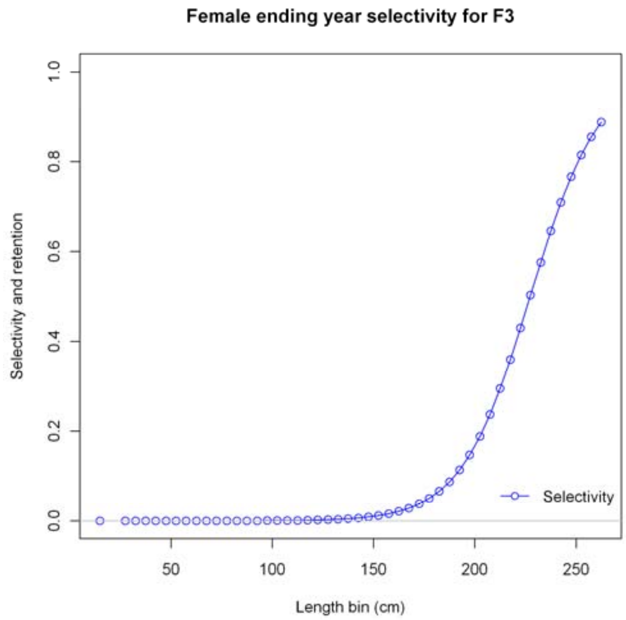

Figure 7.3. Sub-Area 1 length selectivity (F3) Japan Offshore + Distant Water Longline in Region 1-3 (Female = Male; 1951 – 2006).

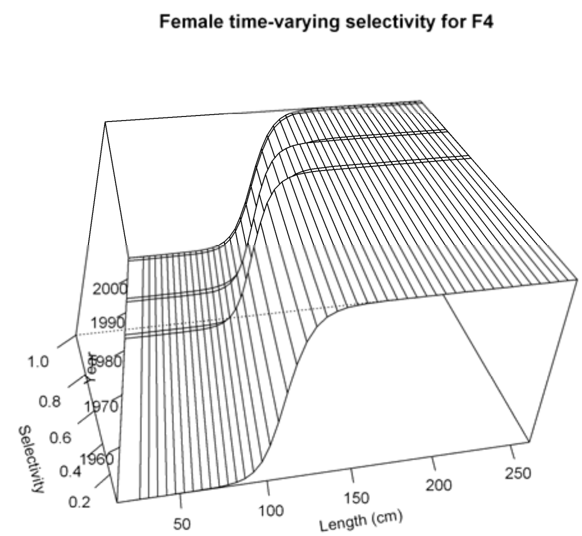

Figure 7.4. Sub-Area 1 length selectivity (F4) Japan Offshore + Distant Water Longline in Region 1-4 (Female = Male; 1951 – 1983, 1984 – 1993, 1994 – 2006).

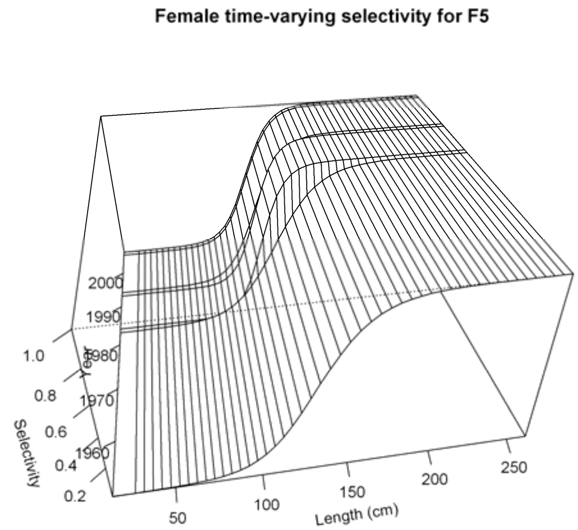

Figure 7.5. Sub-Area 1 length selectivity (F5) Japan Offshore + Distant Water Longline in Region 1-5 (Female = Male; 1951 – 1983, 1984 – 1993, 1994 – 2006).

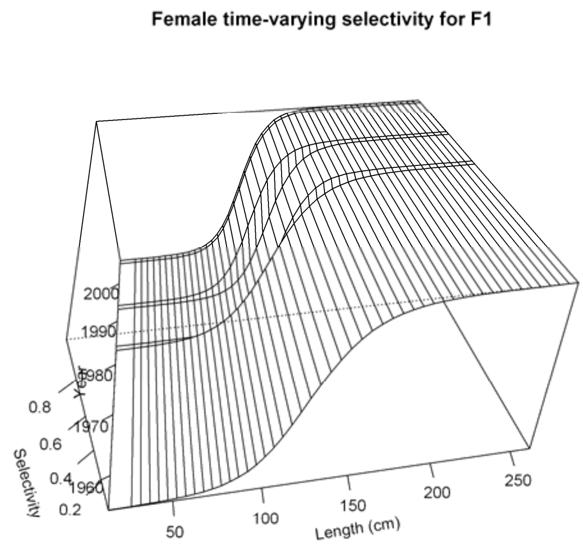

Figure 7.6. Sub-Area 2 length selectivity (F1) Japan Offshore + Distant Water Longline in Region 2-1 (Female = Male; 1951 – 1983, 1984 – 1993, 1994 – 2006).

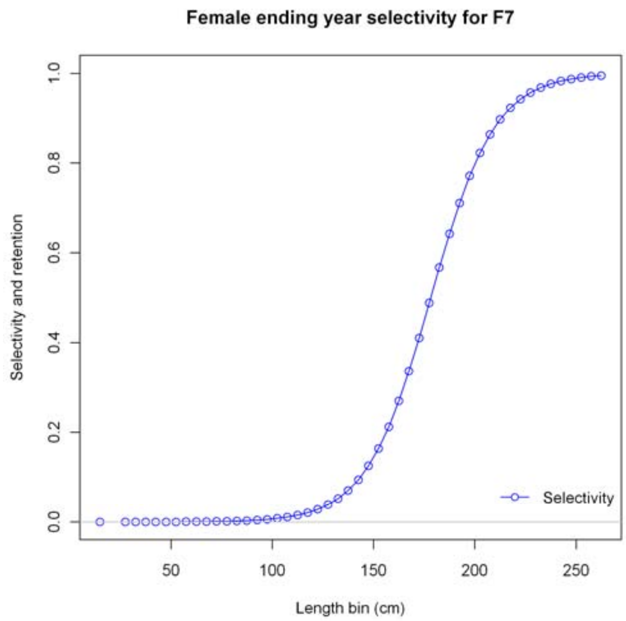

Figure 8. Sub-Area 1 length selectivity (F7) Japan Driftnet in Region 1-1 (Females = Males; 2004 – 2006).

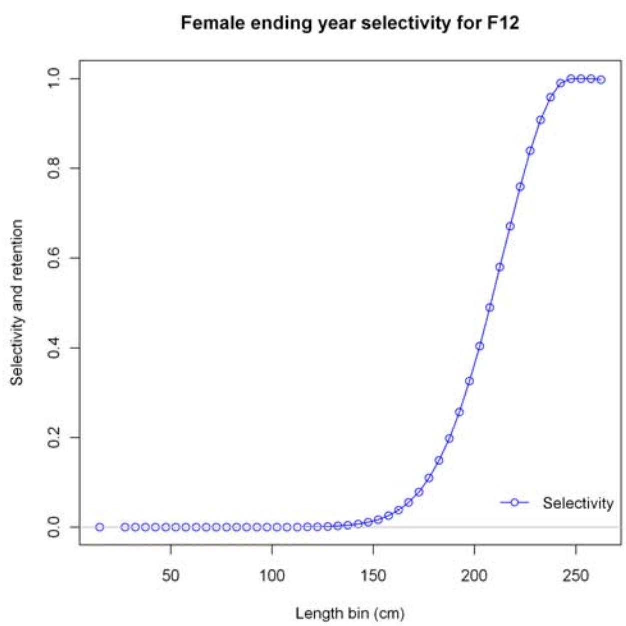

Figure 9. Sub-Area 1 length selectivity (F12) Japan Other Primarily Harpoon in Region 1-1 (Females=Males; 2006 + 2007).

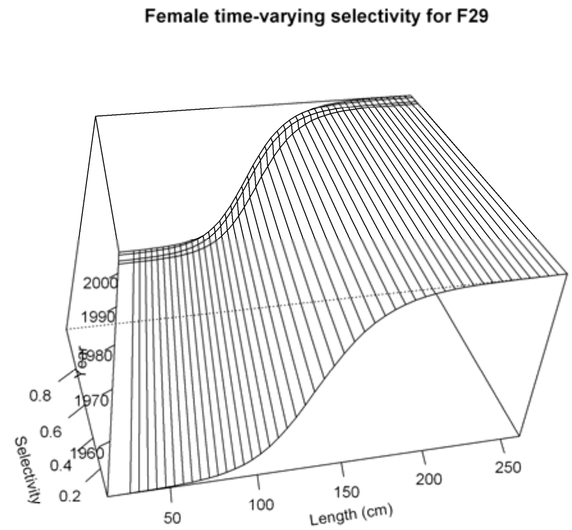

Figure 10. Sub-Area 1 length selectivity (F29) US Hawaii Longline Shallow Set (Females=Males; 1995 – 2003, 2004 – 2006).

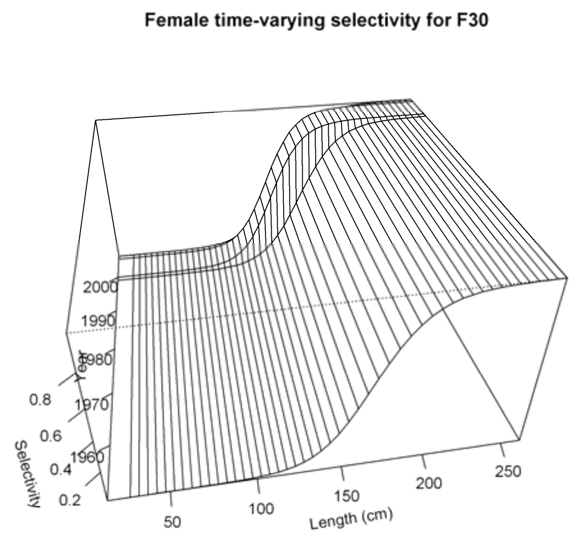

Figure 11. Sub-Area 1 length selectivity (F30) US California Gillnet (Females=Males; 1980 – 1999, 2000 – 2006).

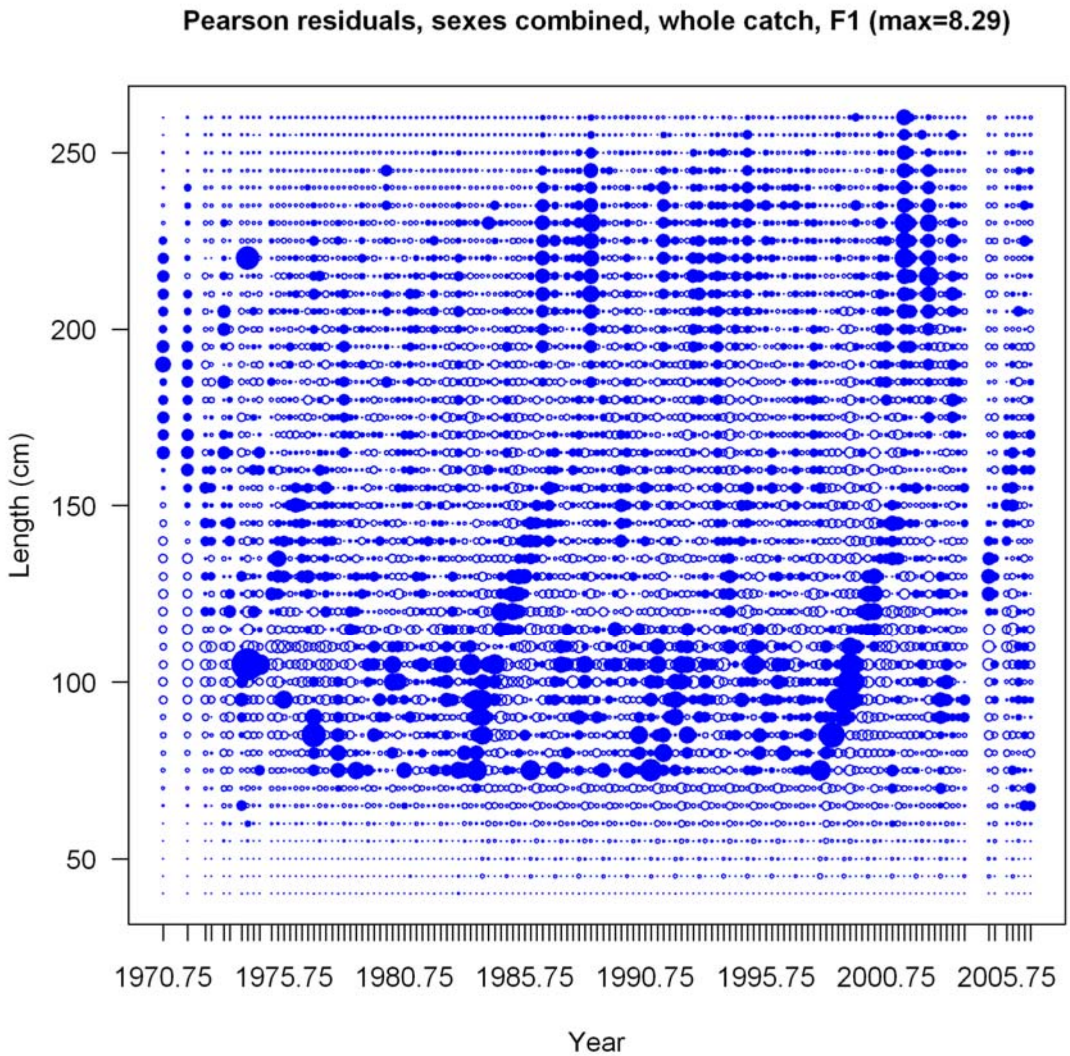

Figure 12.1 Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F1) in Region 1-1. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger “max” indicates a relatively poorer fit.

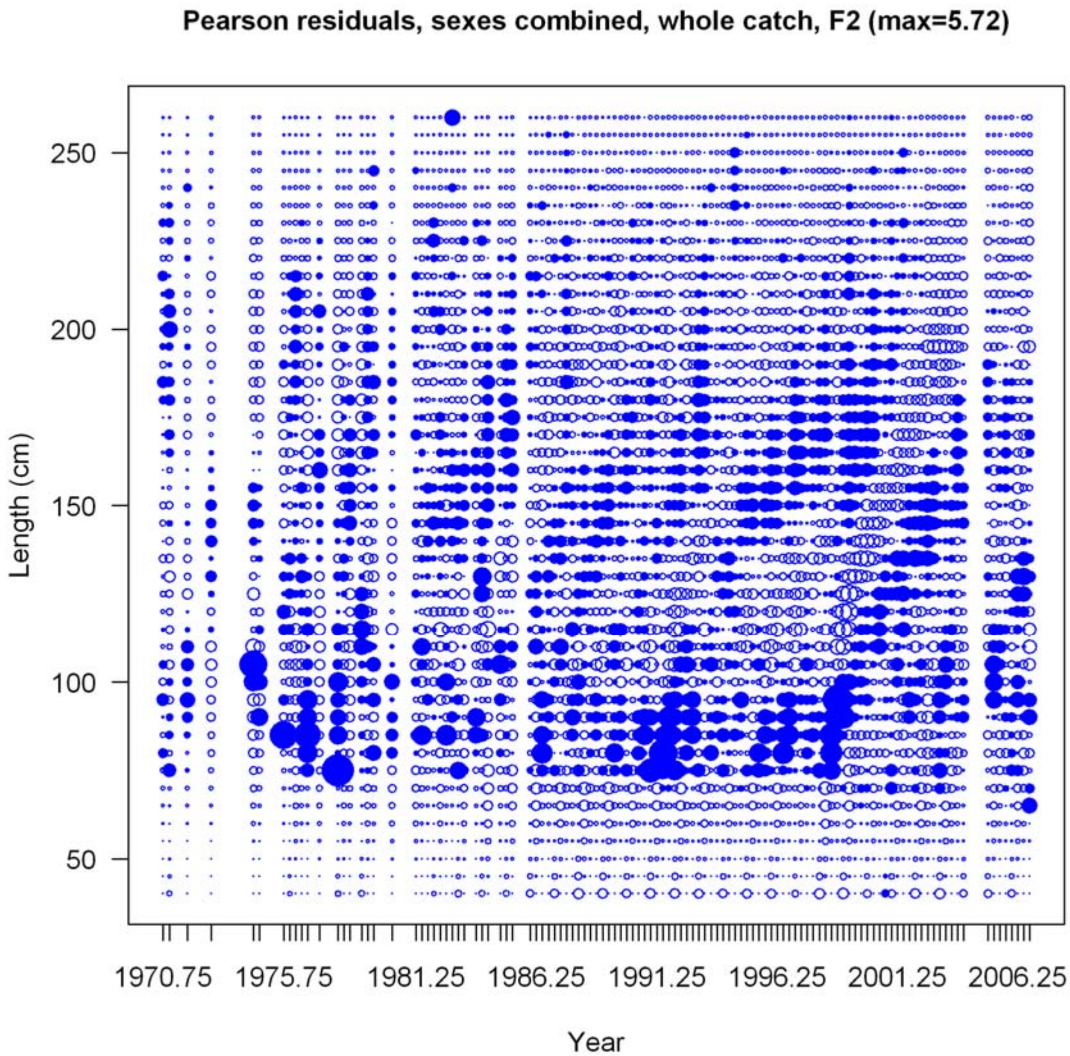

Figure 12.2. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F2) in Region 1-2. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger "max" indicates a relatively poorer fit.

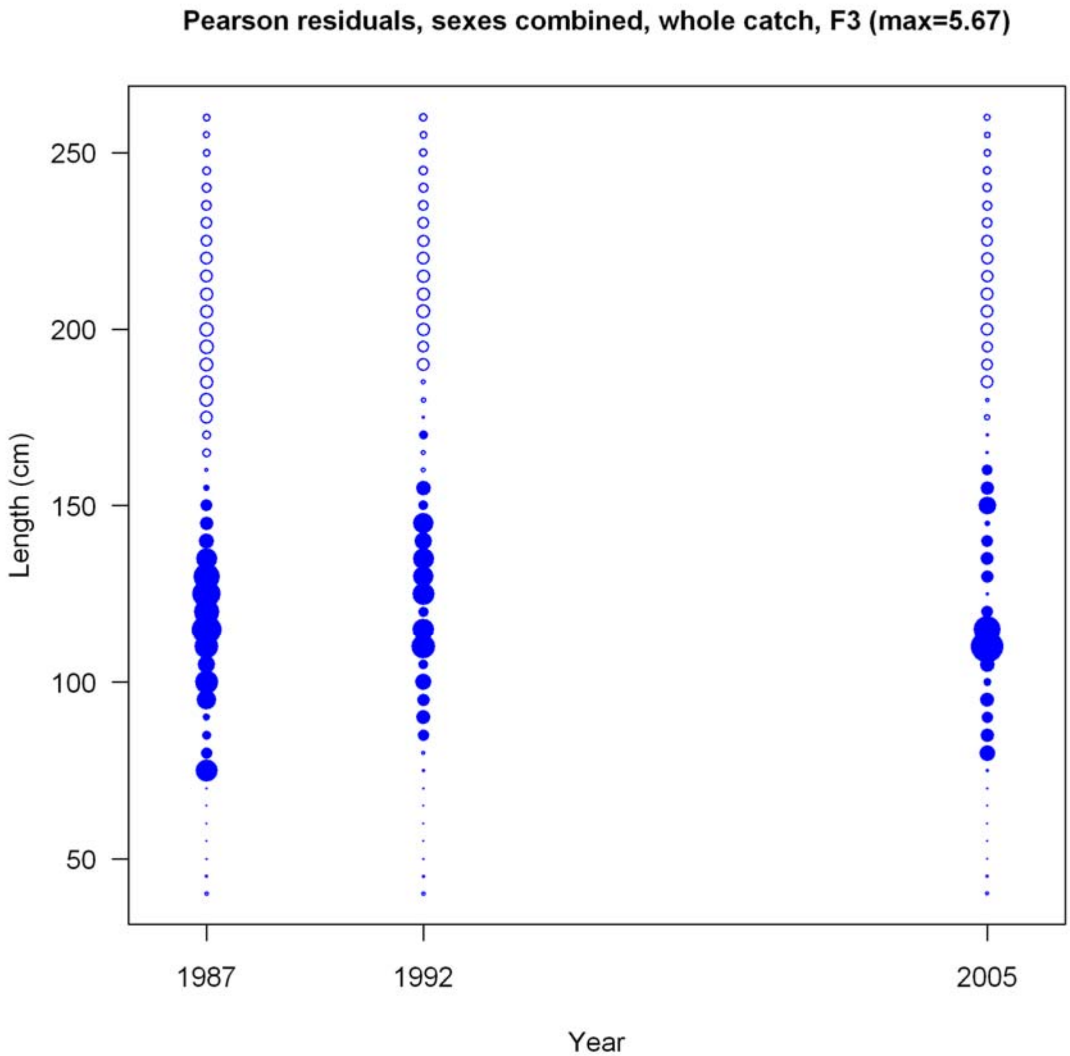

Figure 12.3. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F3) in Region 1-3. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger "max" indicates a relatively poorer fit.

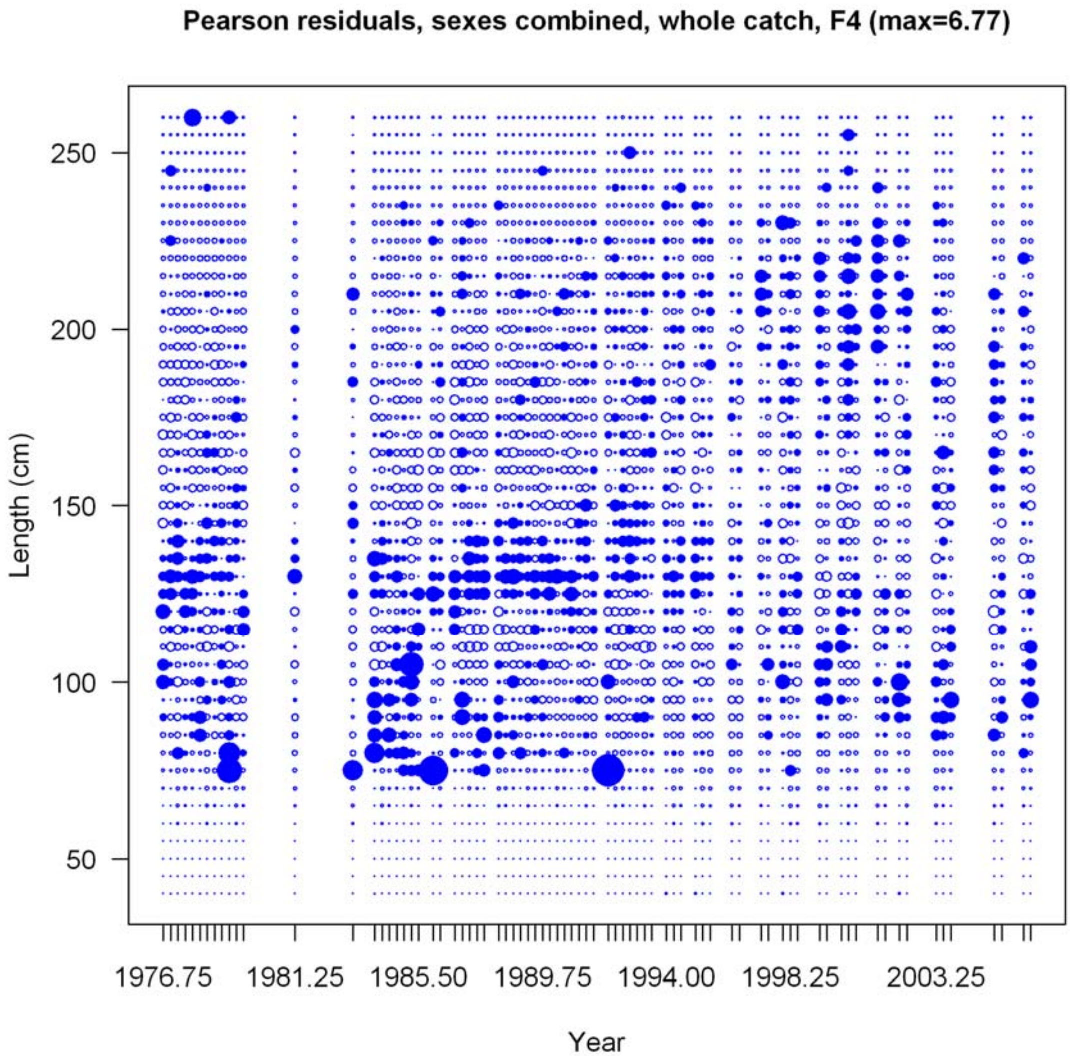

Figure 12.4. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F4) in Region 1-4. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger “max” indicates a relatively poorer fit.

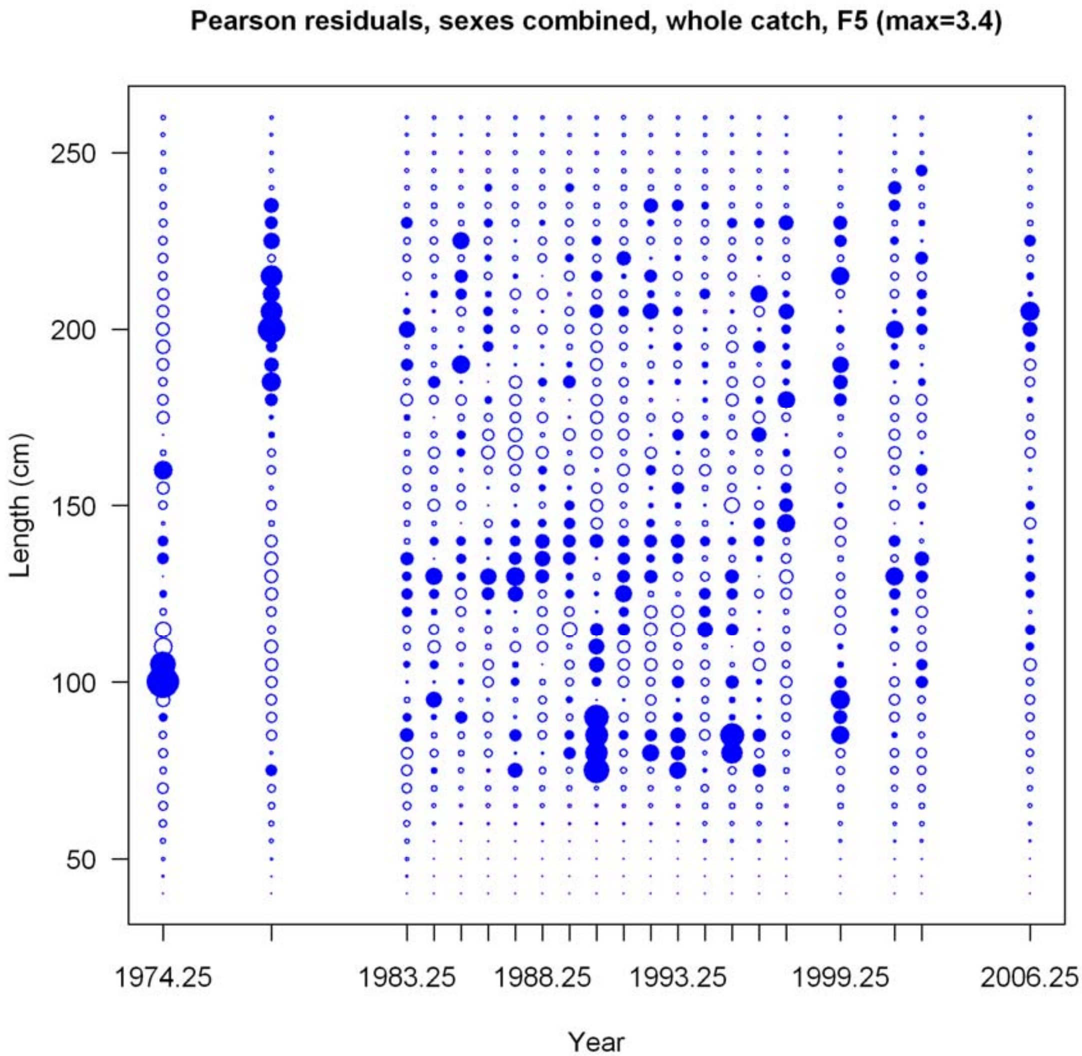

Figure 12.5. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F5) in Region 1-5. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger "max" indicates a relatively poorer fit.

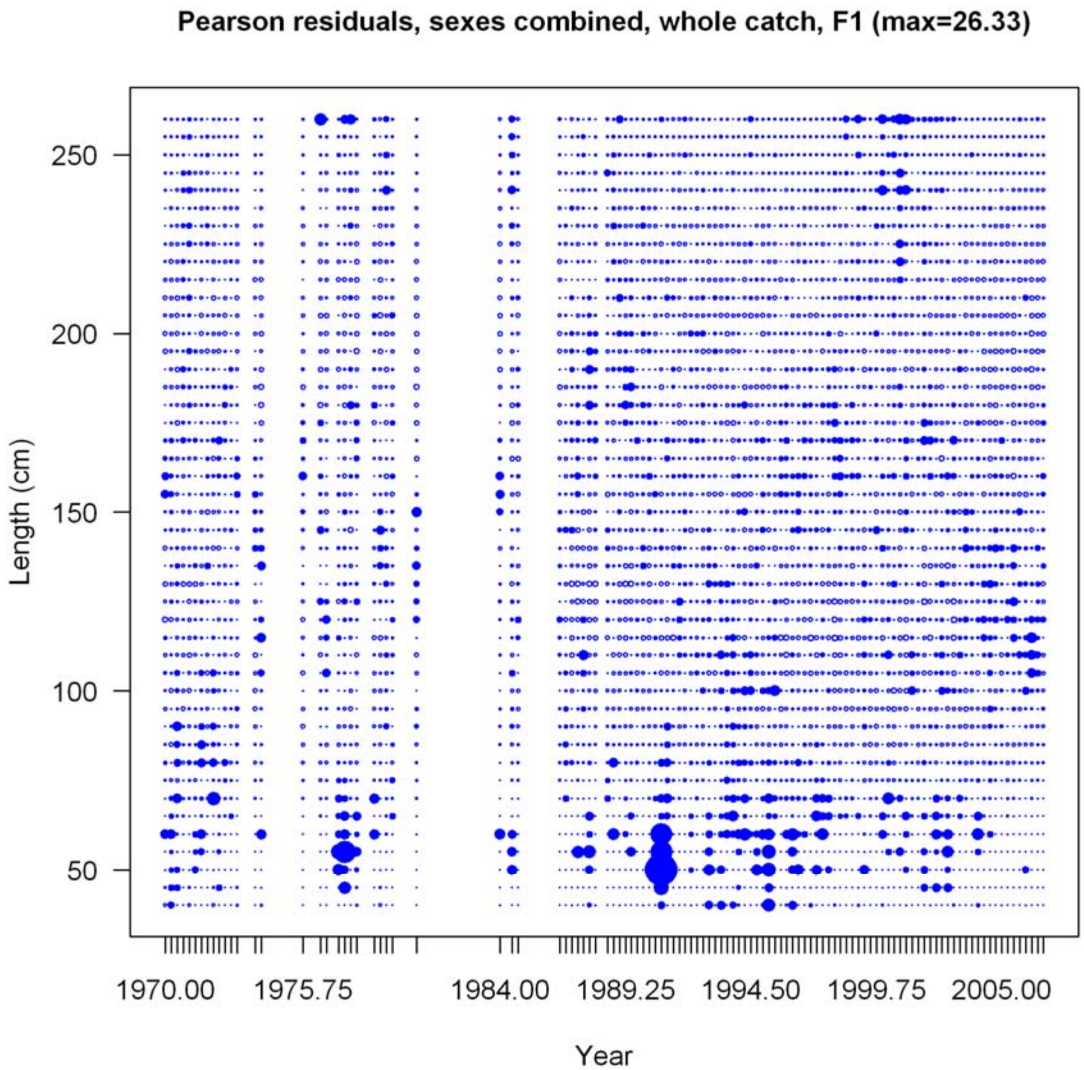

Figure 12.6. Sub-Area 2 length frequency fit for Japan Offshore + Distant Water Longline (F1) in Region 2-1. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger "max" indicates a relatively poorer fit.

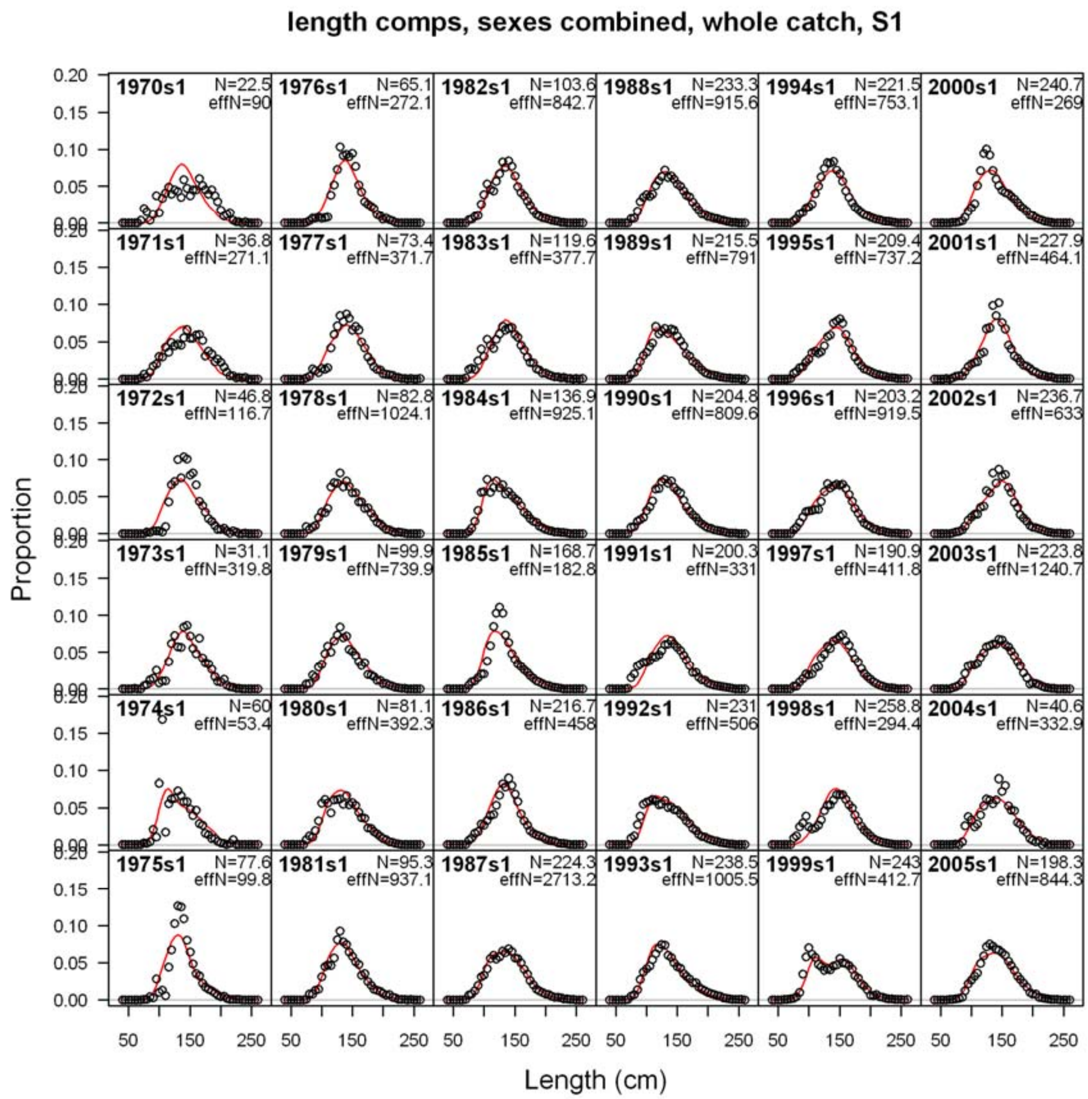

Figure 12.7.1A. Sub-Area 1 annual length frequency Japan Offshore + Distant Water Longline all regions combined (S1) and all quarters combined and assigned to quarter 1 (e.g., 1970s1). Open circles represent observed.

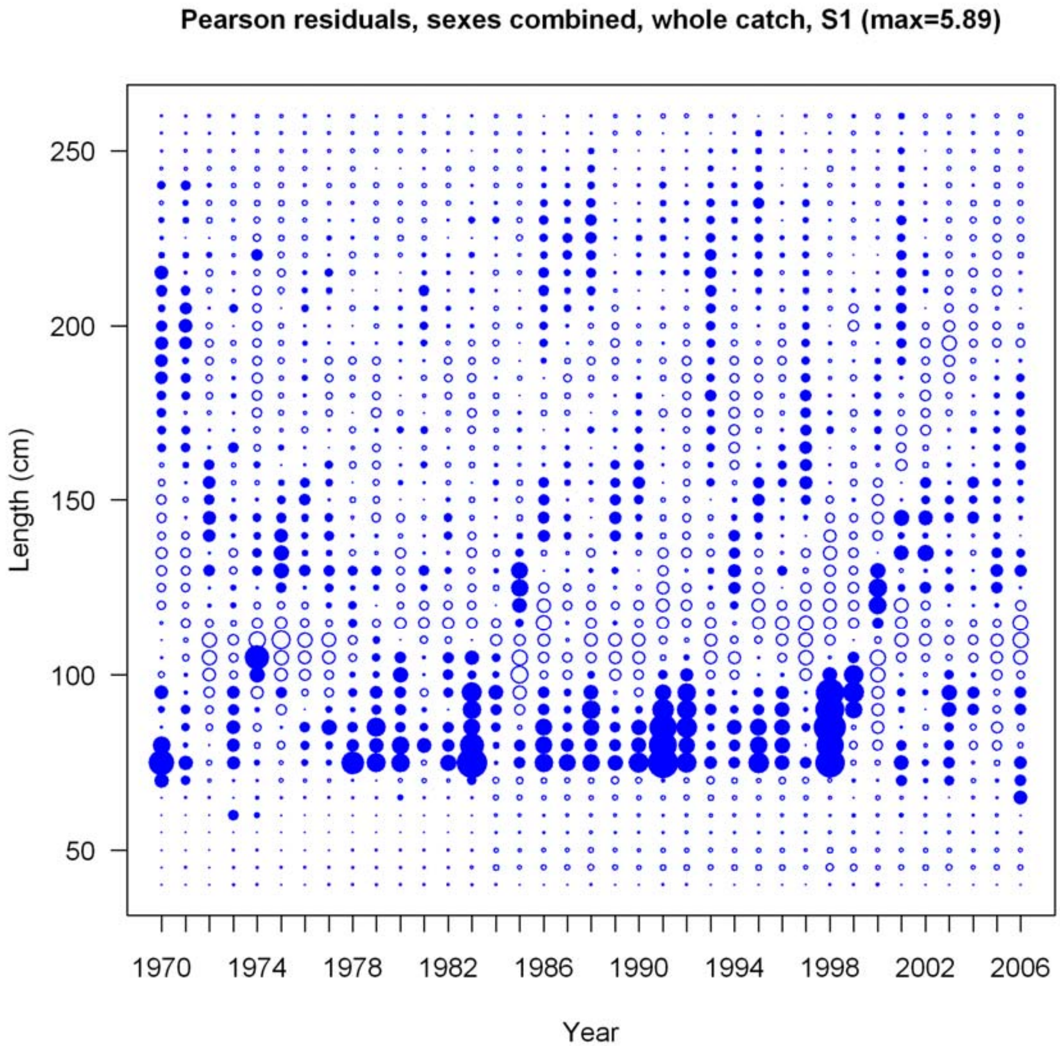

Figure 12.7.1B. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline all regions and quarters combined (S1). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger “max” indicates a relatively poorer fit.

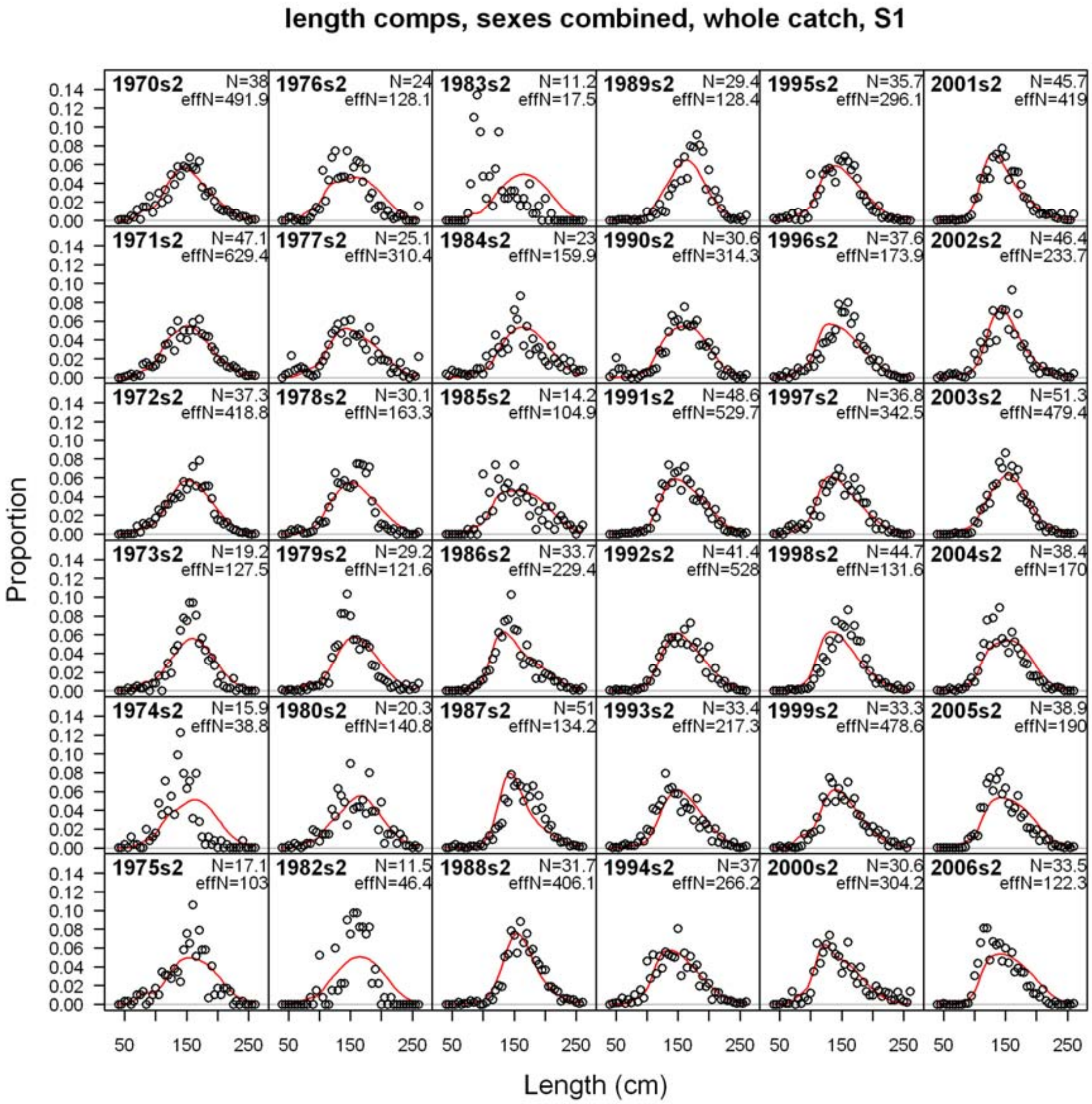

Figure 12.7.2A. Sub-Area 2 annual length frequency Japan Offshore + Distant Water Longline (S1) all quarters combined and assigned to quarter 2 (e.g, 1970s2). Open circles represent observed.

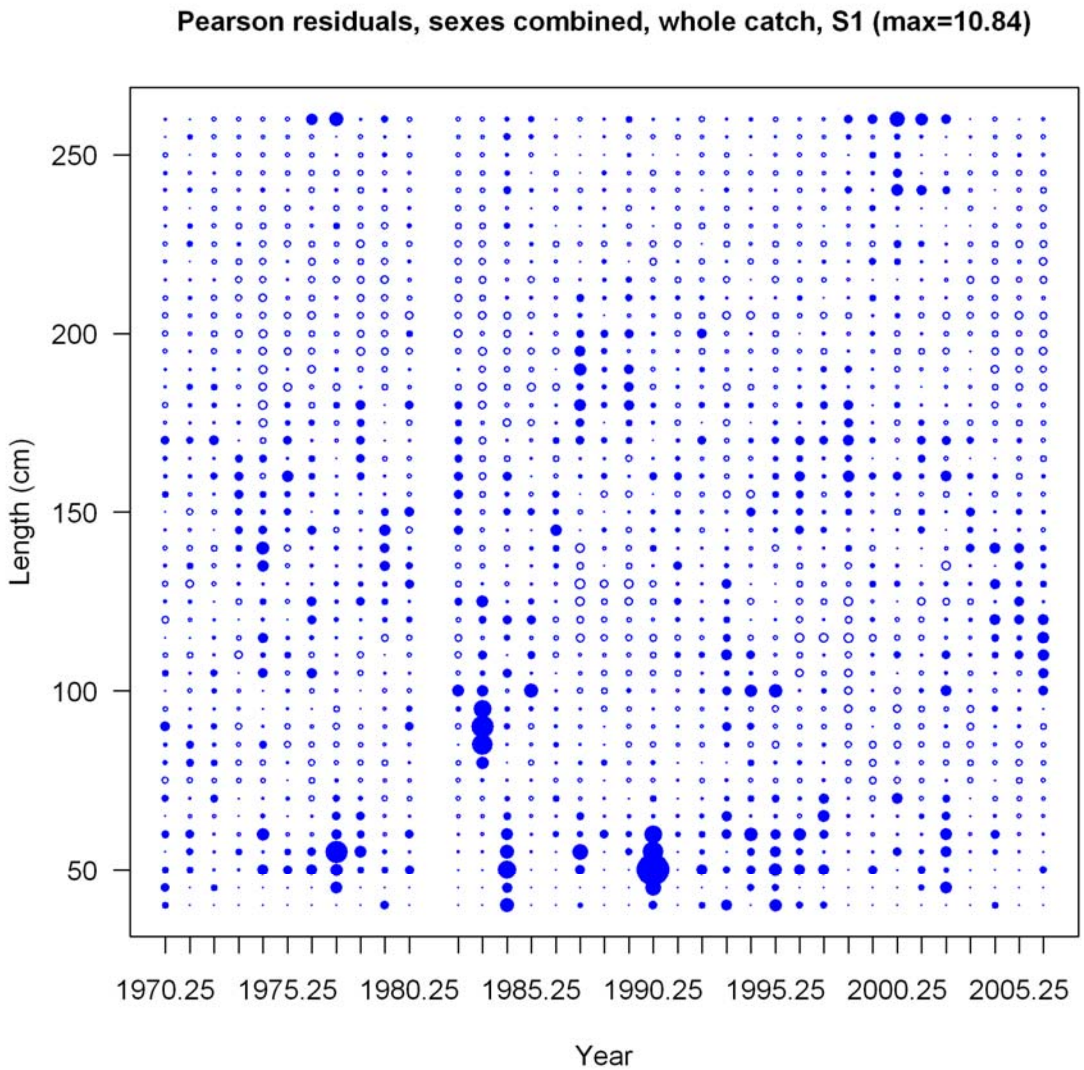

Figure 12.7.2B. Sub-Area 2 length frequency fit for Japan Offshore + Distant Water Longline all quarters combined (S1). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger "max" indicates a relatively poorer fit.

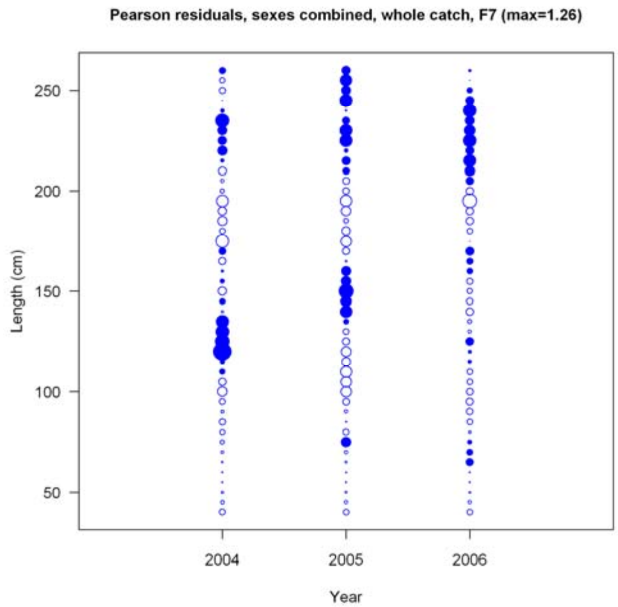

Figure 13. Sub-Area 1 length frequency fit for Japan Driftnet (F7) in Region 1-1. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger “max” indicates a relatively poorer fit.

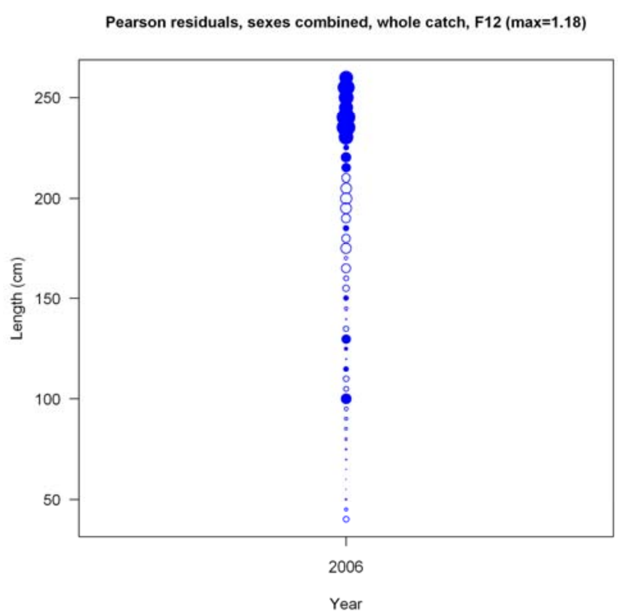

Figure 14. Sub-Area 1 length frequency fit for Japan Other Primarily Harpoon (F12) in Region 1-1. Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger “max” indicates a relatively poorer fit.

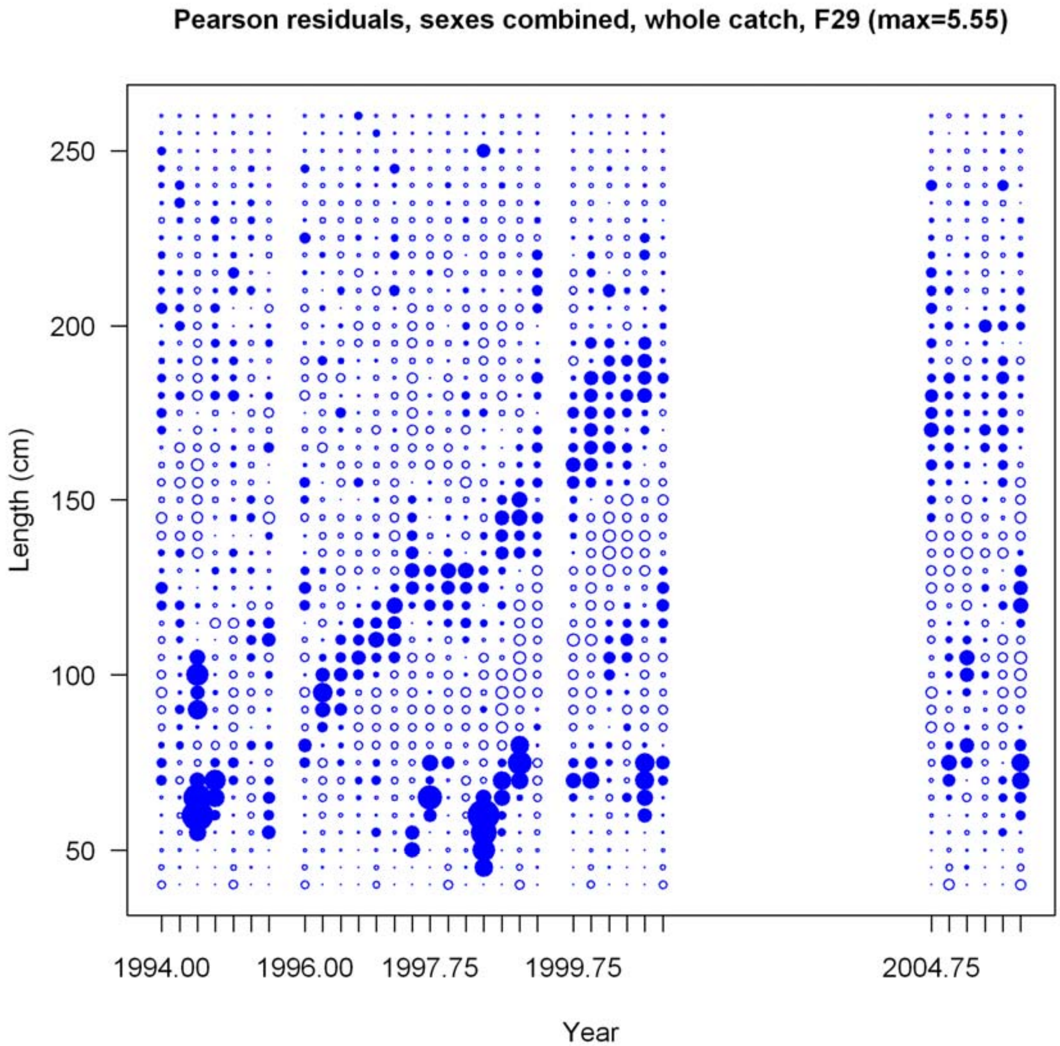

Figure 15. Sub-Area 1 length frequency fit for US Hawaii Longline Shallow Set (F29). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger "max" indicates a relatively poorer fit.

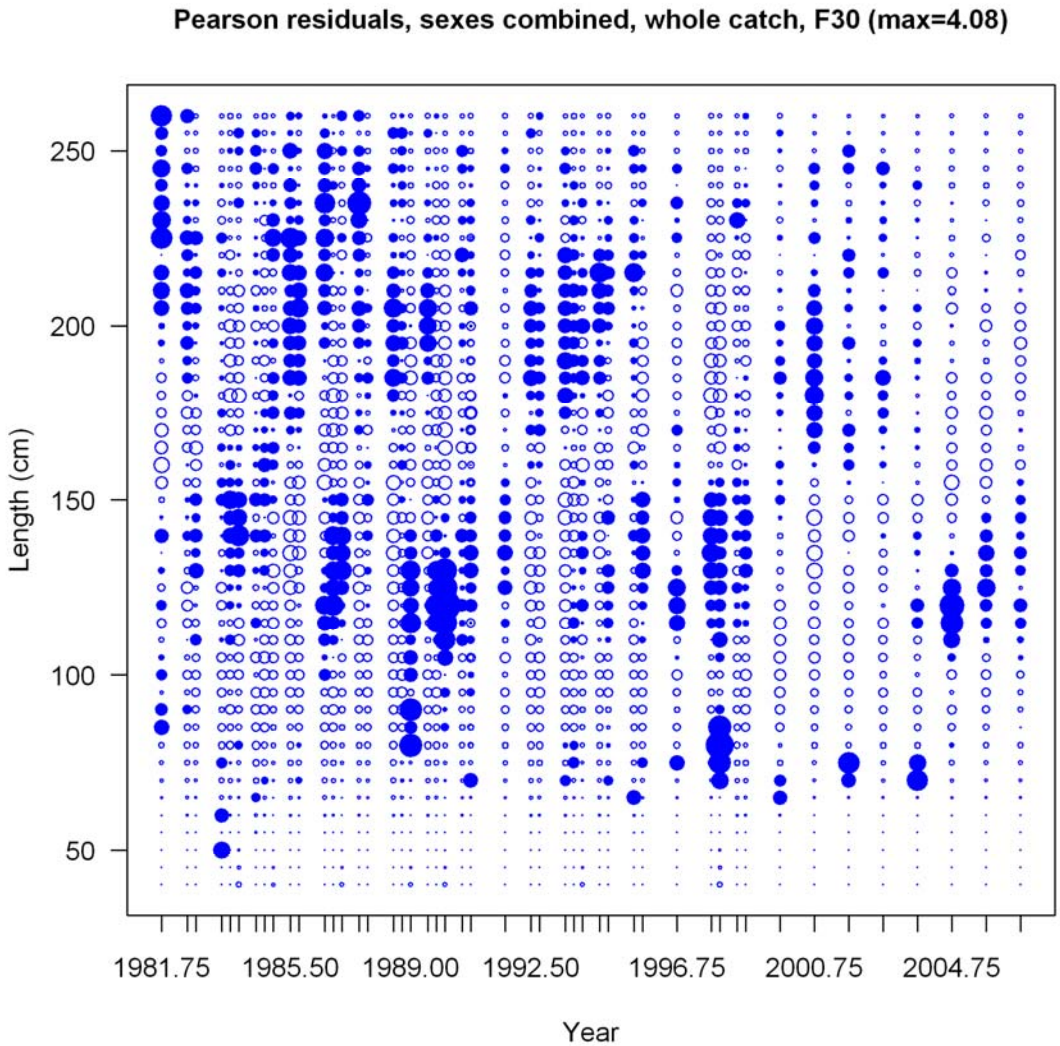

Figure 16. Sub-Area 1 length frequency fit for US California Gillnet (F30). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed. A relatively larger "max" indicates a relatively poorer fit.

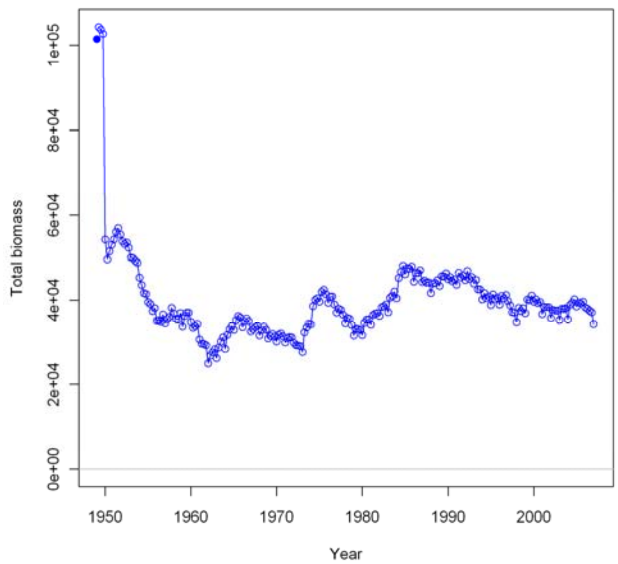

Figure 17.1. Sub-Area 1 Stock Synthesis model estimated total biomass (mt).

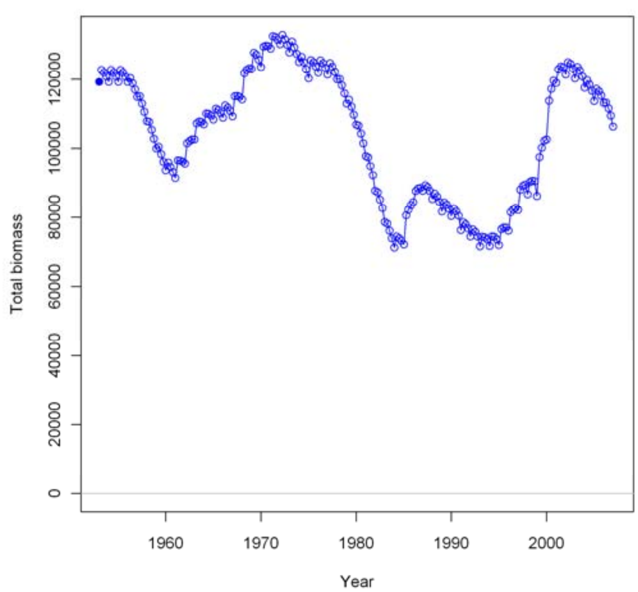

Figure 17.2. Sub-Area 2 Stock Synthesis model estimated total biomass (mt).

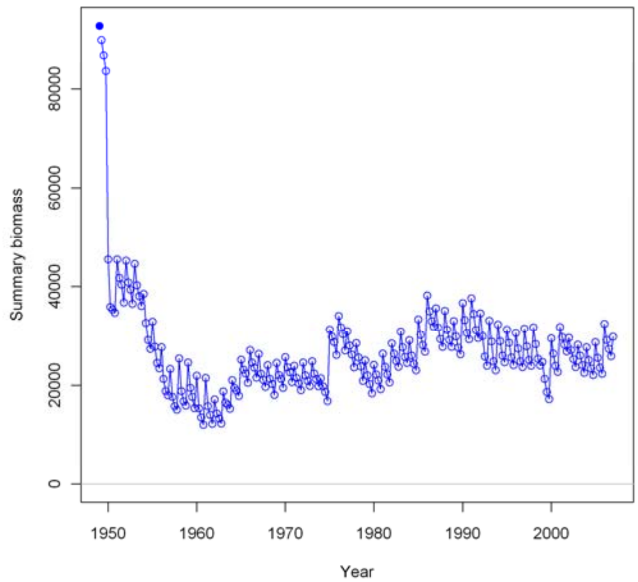

Figure 18.1. Sub-Area 1 Stock Synthesis model estimated summary biomass (Age 2+ mt).

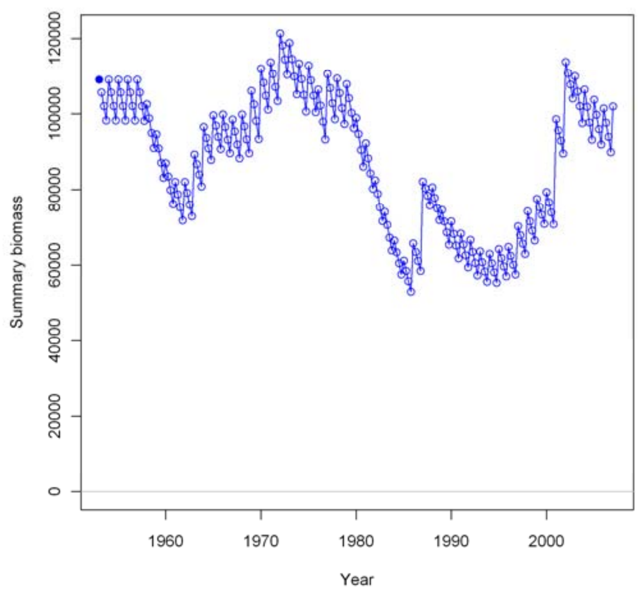

Figure 18.2. Sub-Area 2 Stock Synthesis model estimated summary biomass (Age 2+ mt).

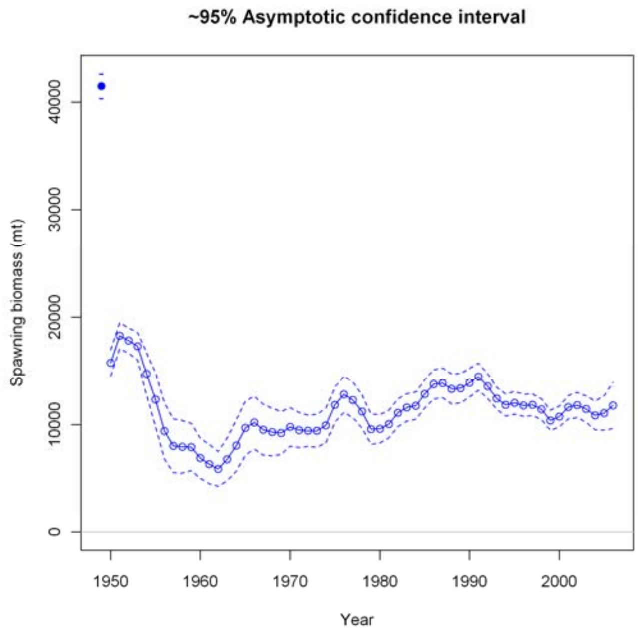

Figure 19.1. Sub-Area 1 model estimated mature female spawning biomass (mt) and 95% confidence interval calculated as +-2 * (model estimated se of annual spawning biomass).

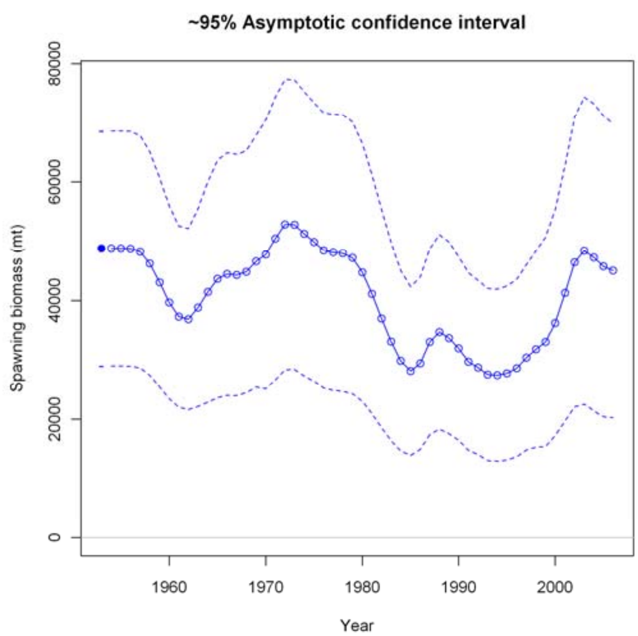

Figure 19.2 Sub-Area 2 model estimated mature female spawning biomass (mt) and 95% confidence interval calculated as +-2 * (model estimated se of annual spawning biomass).

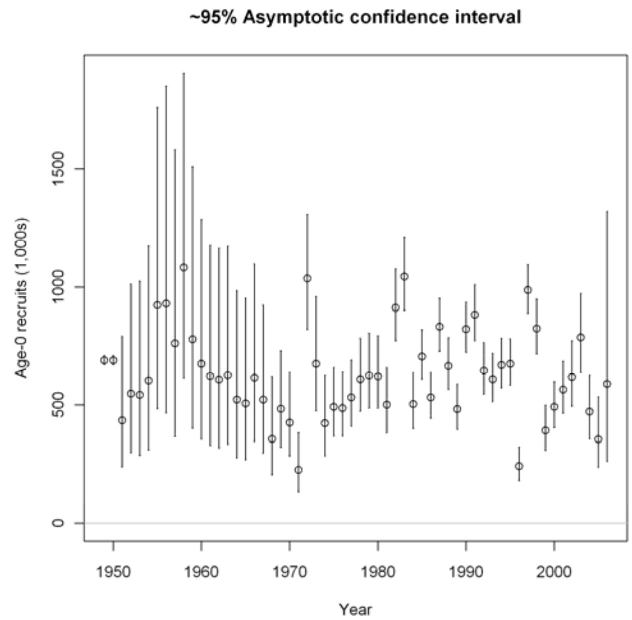

Figure 20.1. Sub-Area 1 model estimated age-0 recruitment (1,000s).

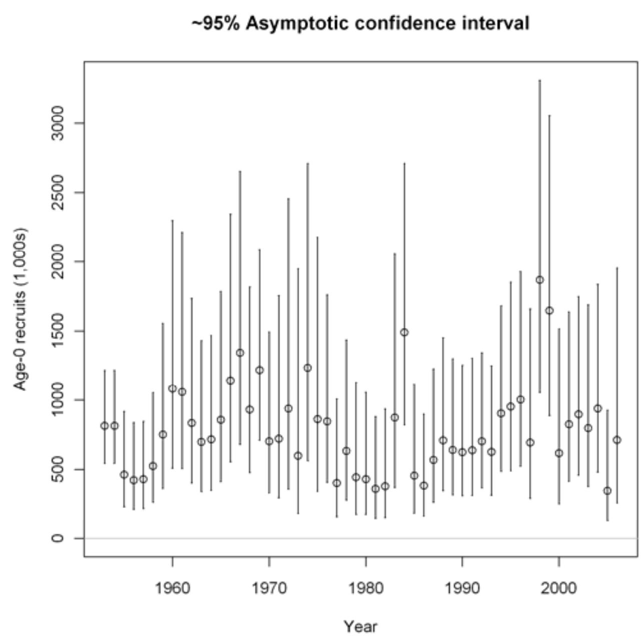

Figure 20.2. Sub-Area 2 model estimated age-0 recruitment (1,000s).

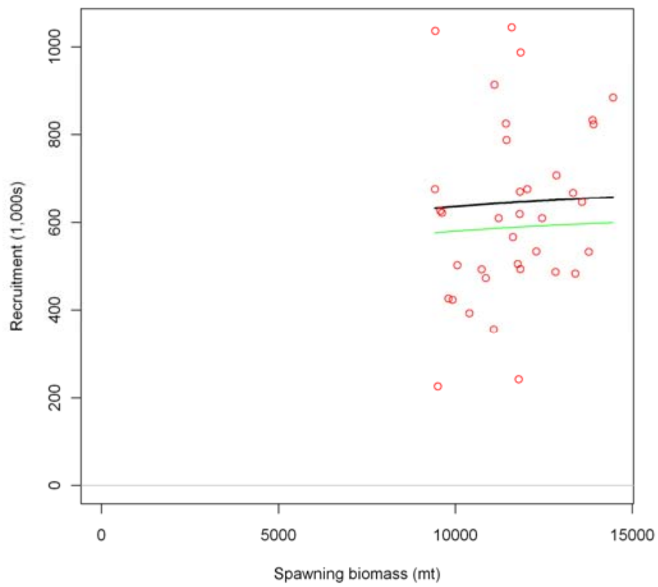

Figure 21.1. Sub-Area 1 model estimated Beverton-Holt spawner-recruit relationship for a fixed steepness (h = 0.9). Bold line is not biased adjusted.

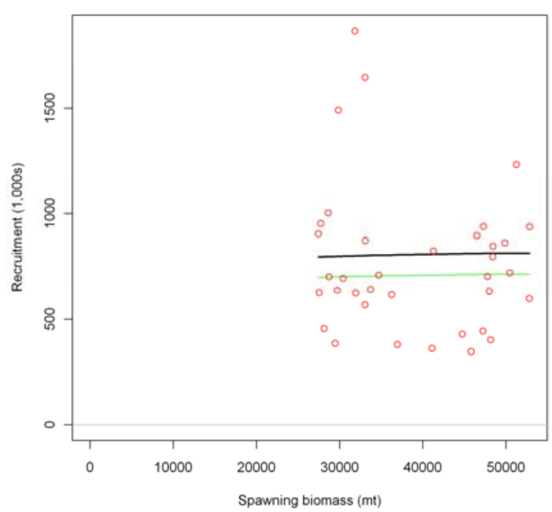

Figure 21.2. Sub-Area 2 model estimated Beverton-Holt spawner-recruit relationship for a fixed steepness (h = 0.9). Bold line is not biased adjusted.

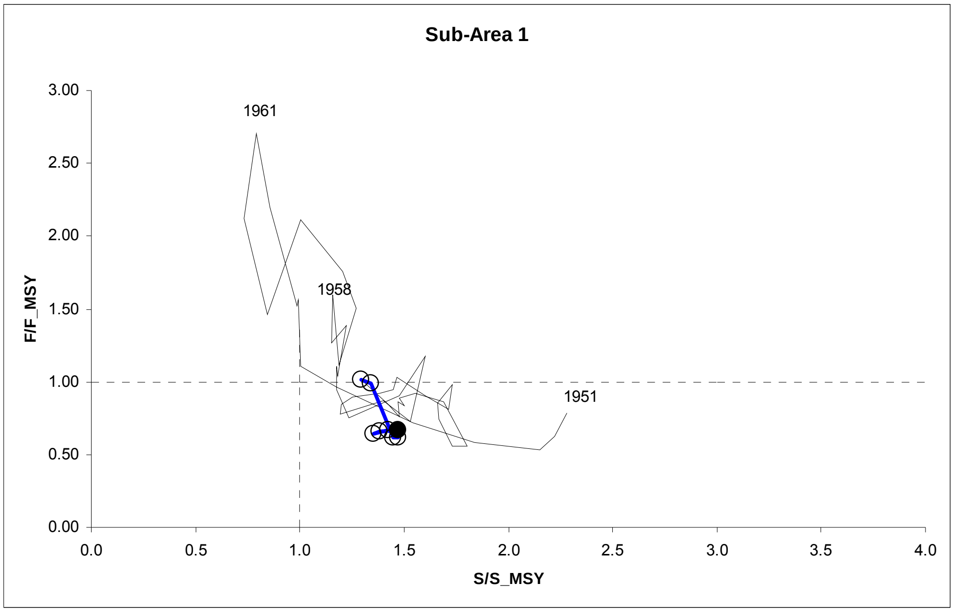

Figure 22.1 Sub-Area 1 Stock Synthesis model "Kobe" plots of female spawning biomass (S) relative to female spawning biomass at MSY (S_MSY) and fishing mortality (F) relative to fishing mortality at MSY (F_MSY). Bold line represents the years 1999 – 2006; Solid circle represents year 2006.

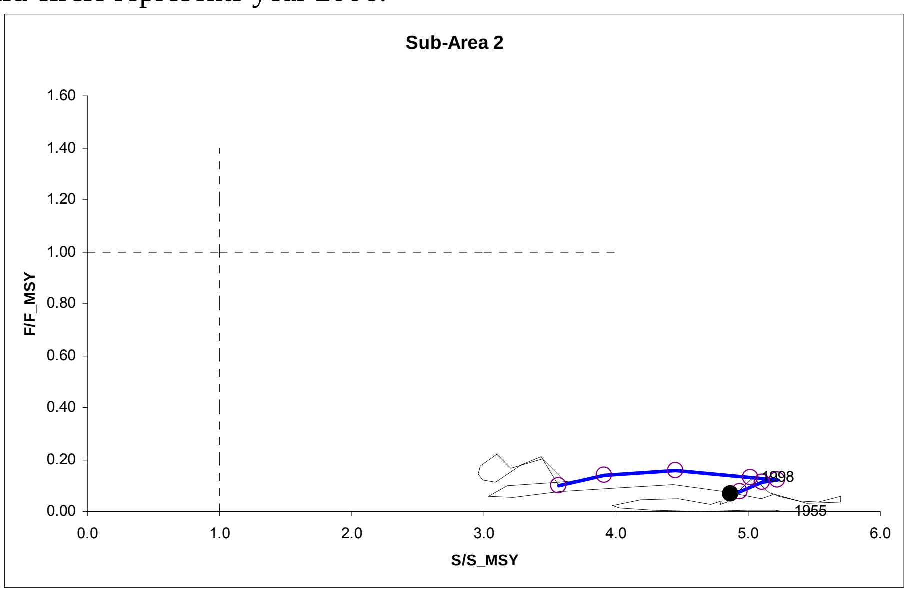

Figure 22.2 Sub-Area 2 Stock Synthesis model "Kobe" plots of female spawning biomass (S) relative to female spawning biomass at MSY (S_MSY) and fishing mortality (F) relative to fishing mortality at MSY (F_MSY). Bold line represents the years 1999 – 2006; Solid circle represents year 2006.

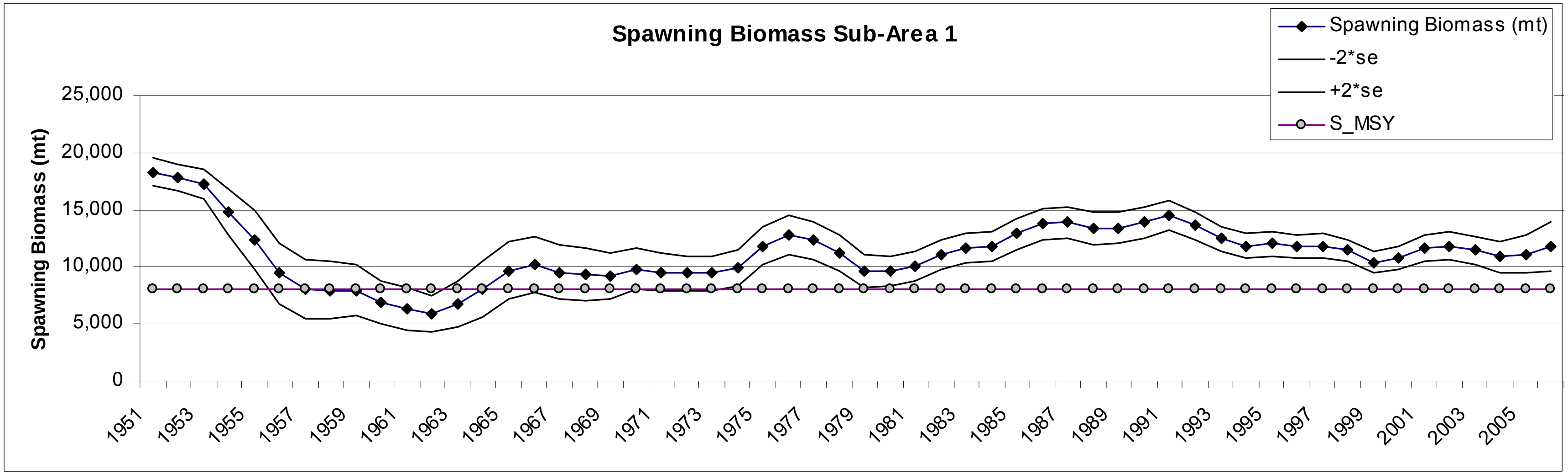

Figure 23.1. Sub-Area 1 Stock Synthesis model estimated female spawning biomass (S) along with female spawning biomass at MSY (S_MSY).

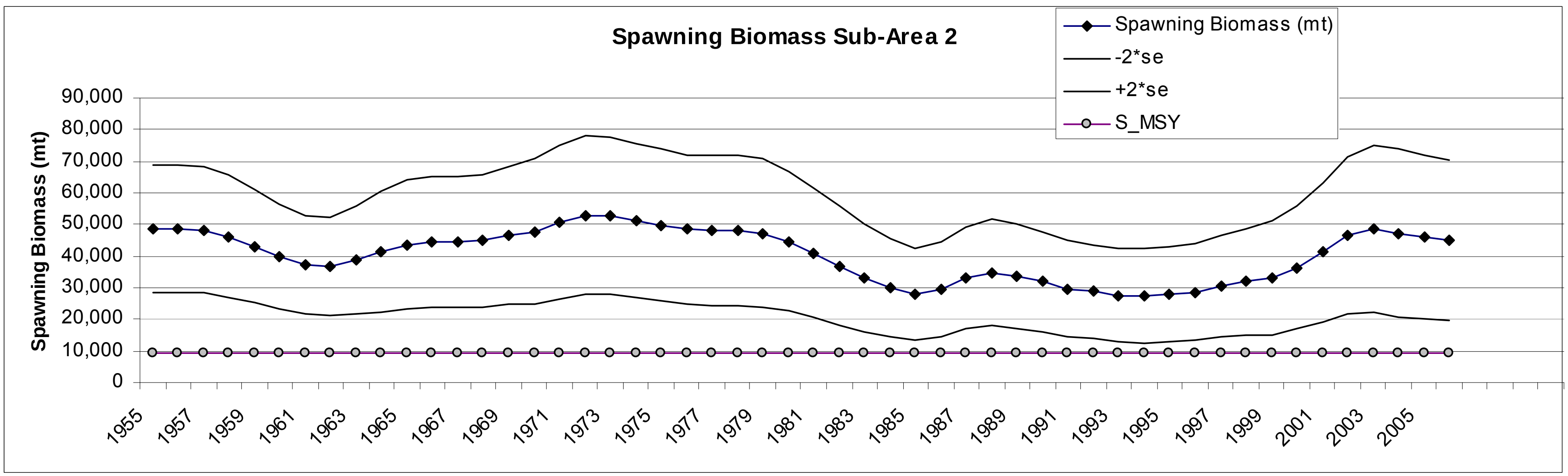

Figure 23.2. Sub-Area 2 Stock Synthesis model estimated female spawning biomass (S) along with female spawning biomass at MSY (S_MSY).

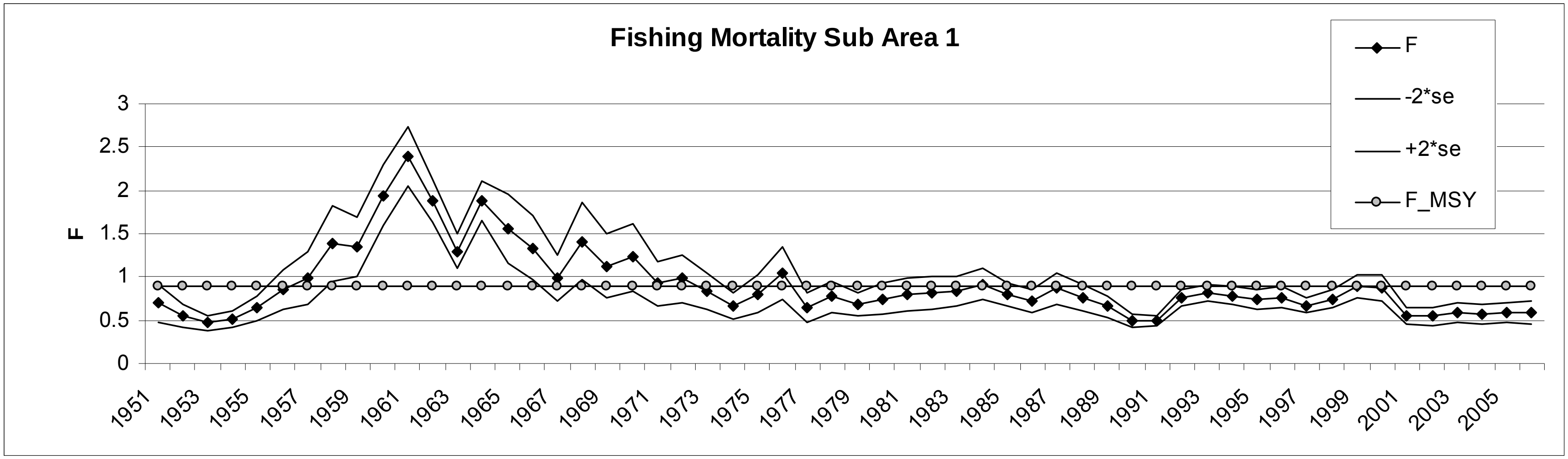

Figure 24.1. Sub-Area 1 Stock Synthesis model estimated fishing mortality (F) along with fishing mortality at MSY (F_MSY).

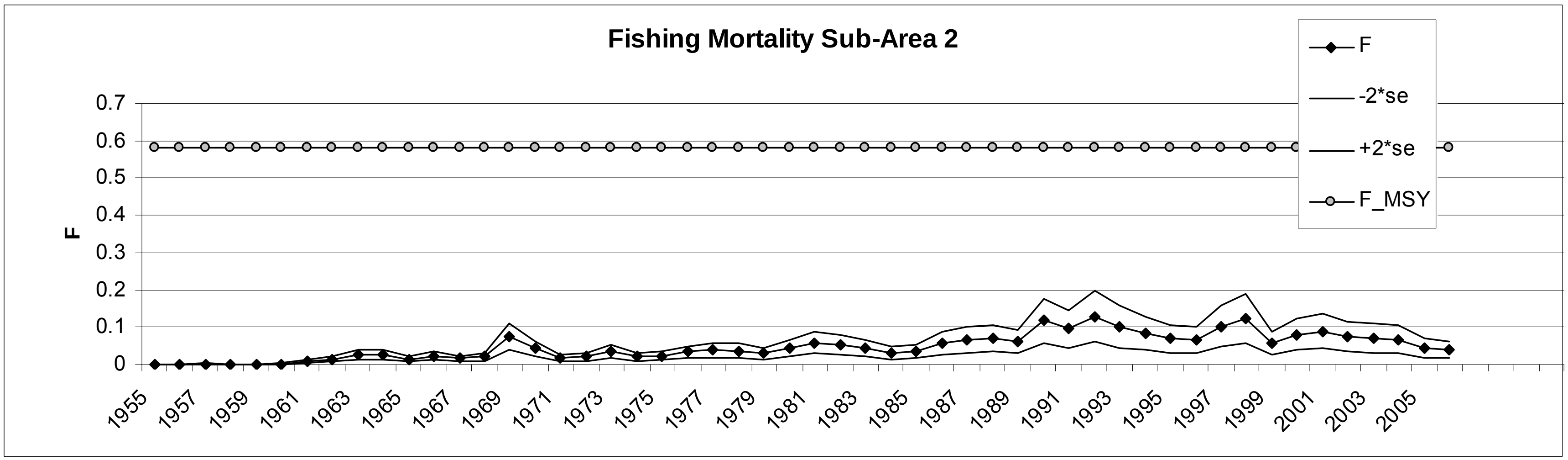

Figure 24.2. Sub-Area 2 Stock Synthesis model estimated fishing mortality (F) along with fishing mortality at MSY (F_MSY).

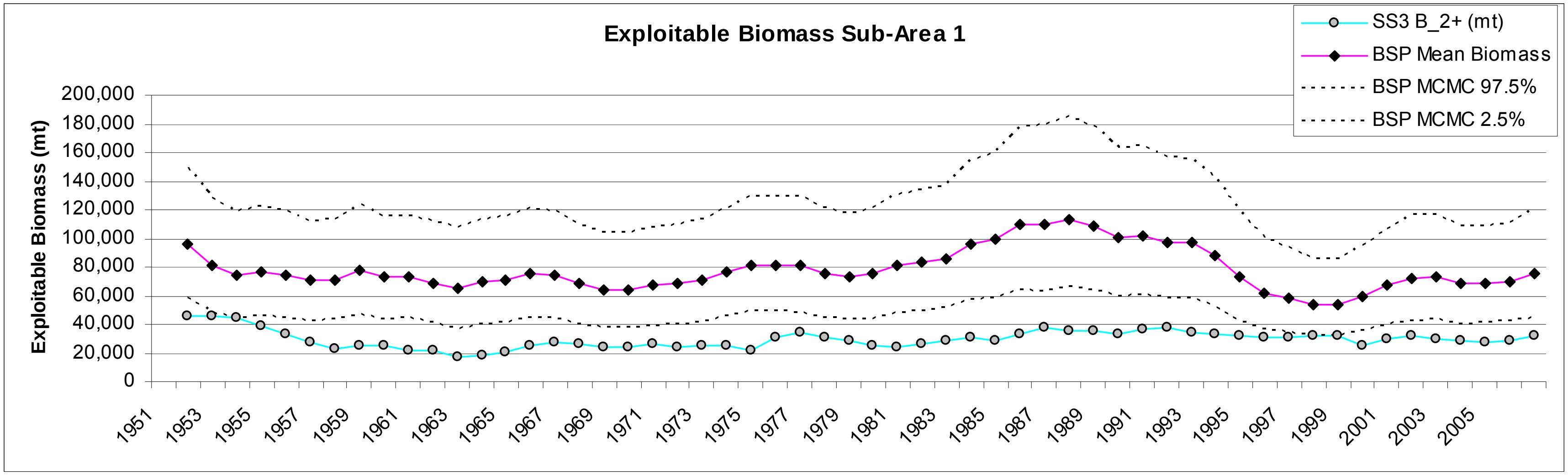

Figure 25.1. Sub-Area 1 Stock Synthesis model estimated time-series of age 2+ biomass (B_2+) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass (BSP Mean Biomass) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak and Ishimura 2009, BILL-WG 2009b).

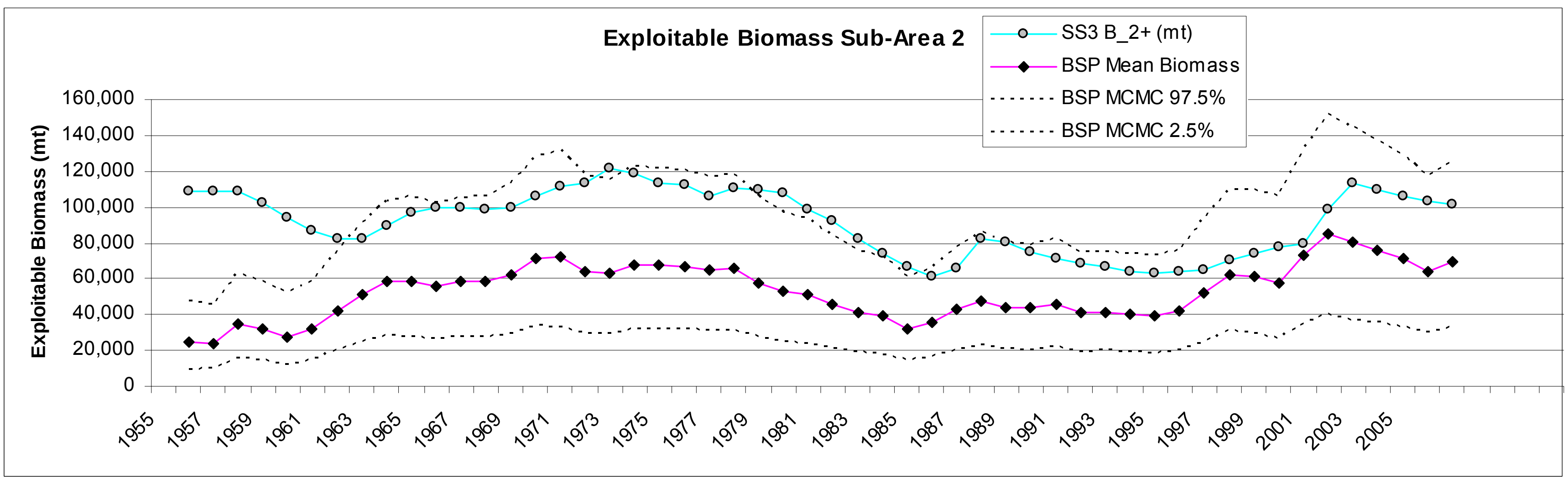

Figure 25.2. Sub-Area 2 Stock Synthesis model estimated time-series of age 2+ biomass (B_2+) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass (BSP Mean Biomass) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak and Ishimura 2009, BILL-WG 2009b)

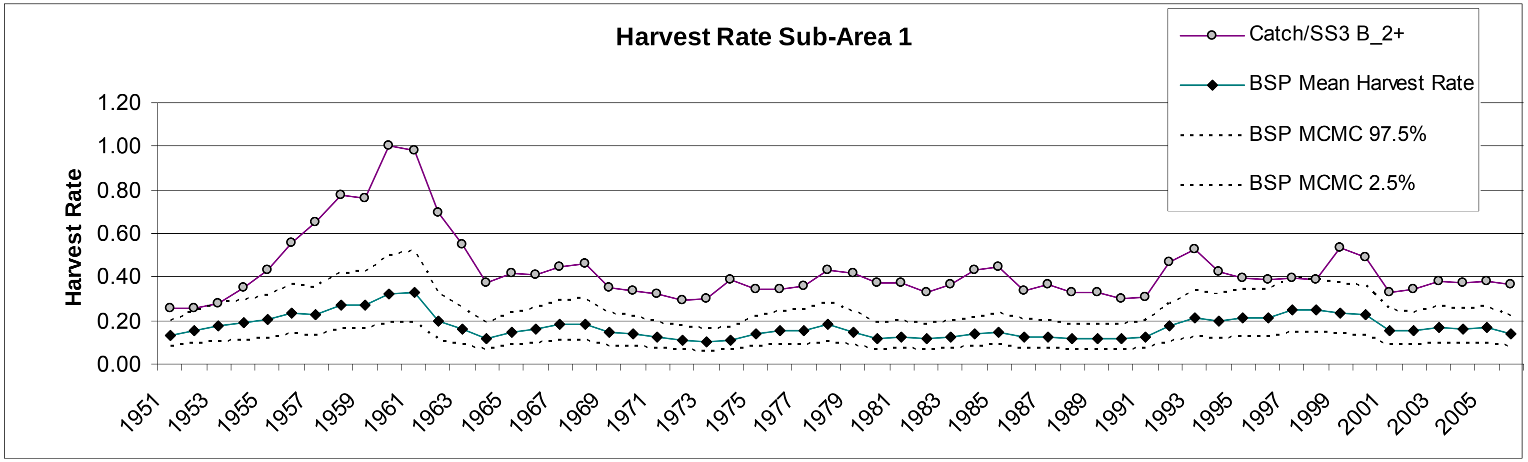

Figure 26.1. Sub-Area 1 Stock Synthesis model estimated time series of total exploitation (Catch mt)/(B_2+ mt) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass harvest rates (BSP Mean Harvest Rate) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak and Ishimura 2009, BILL-WG 2009b).

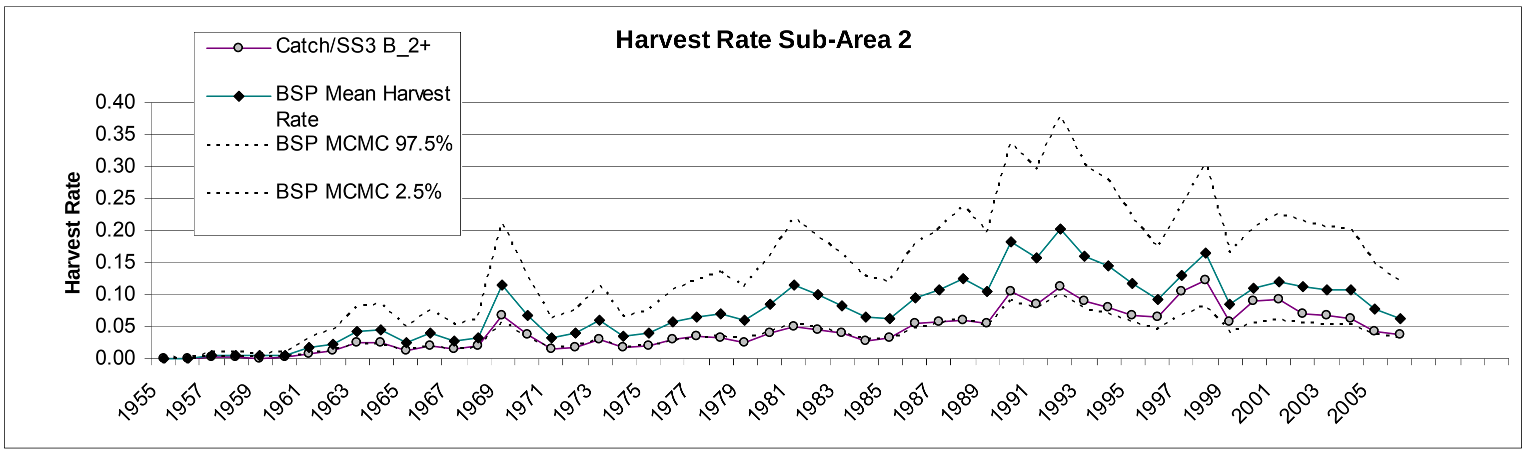

Figure 26.2. Sub-Area 2 Stock Synthesis model estimated time series of total exploitation (Catch mt)/(B_2+ mt) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass harvest rates (BSP Mean Harvest Rate) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak and Ishimura 2009, BILL-WG 2009)

Appendix A. Updated Catch Statistics in Sub-Area 2 (Adapted from Bill-WG 2009c)

Table A.1. Annual total catch (mt) of swordfish in Sub-Area 2 (with updated catch).

Year	Japan[1] Longline	Chinese Taipei[2] Longline	Korea[2] Longline	Spain[2] Longline	Mexico All Gears	Grand Total
1951	1	-	-	-	-	1
1952	1	-	-	-	-	1
1953	2	-	-	-	-	2
1954	15	-	-	-	-	15
1955	12	-	-	-	-	12
1956	11	-	-	-	-	11
1957	168	-	-	-	-	168
1958	138	-	-	-	-	138
1959	98	-	-	-	-	98
1960	138	-	-	-	-	138
1961	645	-	-	-	-	645
1962	1,066	-	-	-	-	1,066
1963	2,228	-	-	-	-	2,228
1964	2,372	-	-	-	-	2,372
1965	1,304	-	-	-	-	1,304
1966	2,059	-	-	-	-	2,059
1967	1,440	21	-	-	-	1,461
1968	1,858	15	-	-	-	1,873
1969	7,281	5	-	-	-	7,286
1970	4,219	25	-	-	-	4,243
1971	1,790	14	-	-	-	1,804
1972	2,172	22	-	-	2	2,196
1973	3,612	18	-	-	4	3,634
1974	2,025	23	-	-	6	2,054
1975	2,330	19	9	-	-	2,359
1976	3,215	34	29	-	-	3,278
1977	3,745	28	33	-	-	3,806
1978	3,601	6	35	-	-	3,642
1979	2,746	25	18	-	7	2,796
1980	3,399	18	62	-	380	3,859
1981	2,952	27	153	-	1,575	4,707
1982	2,159	19	97	-	1,365	3,640
1983	2,693	7	65	-	120	2,885
1984	1,701	13	65	-	47	1,825
1985	1,816	10	91	-	18	1,936
1986	3,020	12	198	-	422	3,652
1987	3,718	22	334	-	550	4,625
1988	4,122	29	163	-	613	4,927
1989	3,080	107	151	-	690	4,028
1990	4,123	31	645	-	2,650	7,449
1991	4,171	44	696	-	861	5,772
1992	5,942	19	372	-	1,160	7,493
1993	4,430	64	385	-	812	5,690
1994	4,158	23	344	-	581	5,106
1995	3,494	14	399	-	437	4,343
1996	3,254	26	568	-	439	4,287
1997	4,202	29	707	6	2,365	7,310
1998	4,541	74	675	115	3,603	9,008
1999	2,588	63	561	29	1,136	4,377
2000	2,964	291	817	831	2,216	7,119
2001	5,313	2,152	517	245	780	9,008
2002	4,370	2,396	391	303	465	7,925
2003	4,192	1,747	182	534	671	7,327
2004	3,182	942	1,060	1,292	270	6,746
2005	2,421	746	287	717	235	4,405
2006	2,204	1,006	-	366	347	3,924

[1] Annual total catch (mt) of swordfish caught by Japanese Offshore + Distant-Water Longline updated to include the area 0 - 20 S and east of 150 W. Japan catch in 2005 and 2006 is provisional.

[2] Annual total catch (mt) of swordfish in Sub-area 2 for longline vessels of Spain (ESP), Korea (KOR), and Chinese Taipei (TWN) estimated from data held by the IATTC.

Table A.2. For comparison, initial estimates of annual total catch (mt) of swordfish in Sub-Area 2 are provided without updated catch (Adapted from Courtney and Wagatsuma 2009).

Year	Japan Longline	Chinese Taipei Longline	Korea Longline	Mexico All Gears	Grand Total
1951	1	-	-	-	1
1952	1	-	-	-	1
1953	2	-	-	-	2
1954	15	-	-	-	15
1955	10	-	-	-	10
1956	8	-	-	-	8
1957	106	-	-	-	106
1958	71	-	-	-	71
1959	68	-	-	-	68
1960	97	-	-	-	97
1961	443	-	-	-	443
1962	768	-	-	-	768
1963	1,306	-	-	-	1,306
1964	1,397	-	-	-	1,397
1965	807	-	-	-	807
1966	1,115	-	-	-	1,115
1967	943	-	-	-	943
1968	1,246	-	-	-	1,246
1969	3,487	-	-	-	3,487
1970	2,368	-	-	-	2,368
1971	1,257	-	0	-	1,257
1972	1,470	-	0	2	1,472
1973	2,420	-	0	4	2,424
1974	1,353	-	0	6	1,359
1975	1,491	-	0	-	1,491
1976	1,900	-	0	-	1,900
1977	2,069	-	110	-	2,178
1978	1,781	-	34	-	1,815
1979	1,459	-	-	7	1,466
1980	1,592	-	32	380	2,004
1981	1,410	-	-	1,575	2,985
1982	1,097	-	24	1,365	2,486
1983	1,294	-	6	120	1,419
1984	826	-	24	47	897
1985	958	-	12	18	988
1986	1,508	-	5	422	1,934
1987	1,857	-	22	550	2,429
1988	1,857	-	14	613	2,484
1989	1,687	-	20	690	2,397
1990	1,931	-	31	2,650	4,611
1991	1,868	-	3	861	2,731
1992	2,530	-	4	1,160	3,694
1993	2,110	-	8	812	2,929
1994	1,939	-	33	581	2,553
1995	1,670	1	5	437	2,114
1996	1,735	4	8	439	2,186
1997	2,143	3	50	2,365	4,561
1998	2,153	15	77	3,603	5,847
1999	1,260	34	66	1,136	2,495
2000	1,671	213	101	2,216	4,201
2001	2,900	978	219	780	4,877
2002	2,193	1,545	220	465	4,423
2003	1,897	984	191	671	3,742
2004	1,446	708	205	270	2,629
2005[1)]	1,168	328	217	235	1,947
2006[1)]	1,138	-	239	347	1,724

[1)] Japan catch in 2005 and 2006 is provisional.

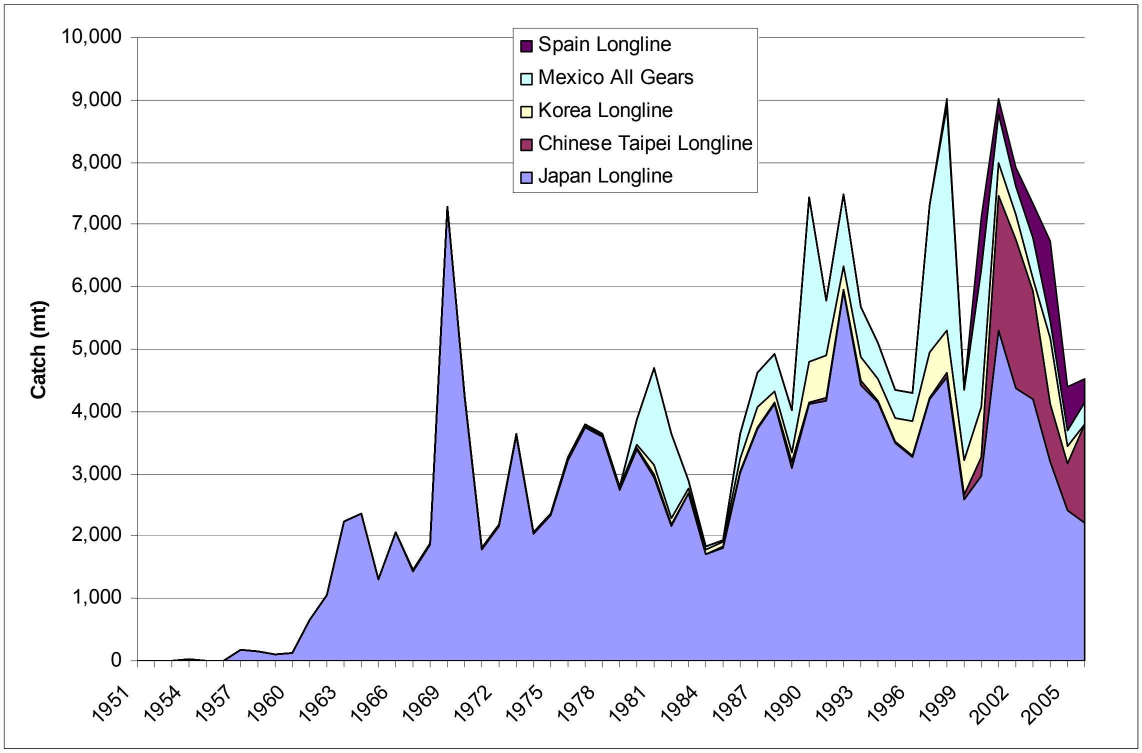

Figure A.1. Annual total catch (mt) of swordfish in Sub-Area 2 (with updated catch).

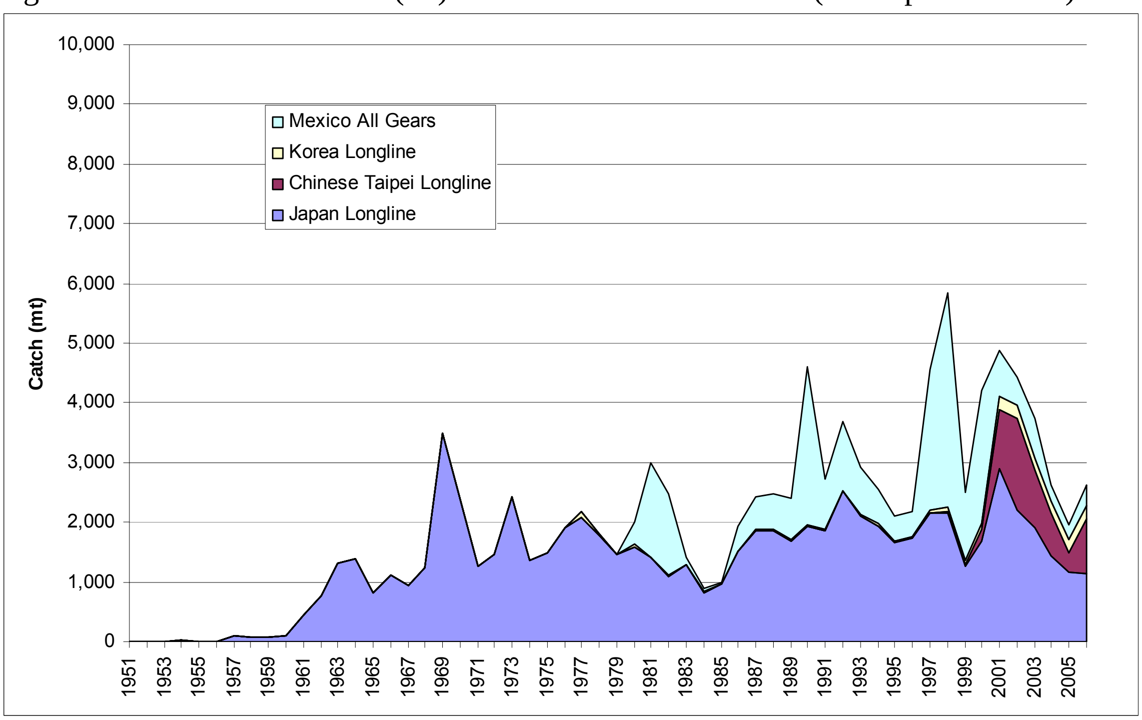

Figure A.2. For comparison, initial estimates of annual total catch (mt) of swordfish in Sub-Area 2 are provided without updated catch.

Appendix B. Assignment of Spawning Quarter Based on Larval Occurrence

For this assessment, swordfish spawning was assigned to quarter 2 based on a review of larval occurrence below (Table B.1).

Table B.1. Assignment of spawning quarter based on larval occurrence.

Sample Location	Egg/Larval Occurrence
Western North Pacific[1]	Larval Capture April through July.
Central North Pacific[1,2]	Eggs and larvae occurred only in the months of April through July.
Eastern Pacific[1]	Little to no effort across to the far eastern Pacific.
Equatorial North Pacific[1] (Equator to 10 deg. N)	Lower larval swordfish catches spread out over all the seasons with highest larval captures in April-June.

[1]Nishikawa et al. (1985) larval capture data for 1956-1981.
[1,2]NOAA PIFSC egg and larval collections from Kona Hawaii 1997 to 2005 (Pers. Comm. Robert Humphrys NOAA PIFSC).

Age at recruitment in Stock Synthesis will depend on estimated quarterly selectivity at length. For example, average quarterly selectivity at age (1990 – 2006) was calculated here from the estimated quarterly selectivity at length in (Courtney and Piner 2009b) (Figure B1).

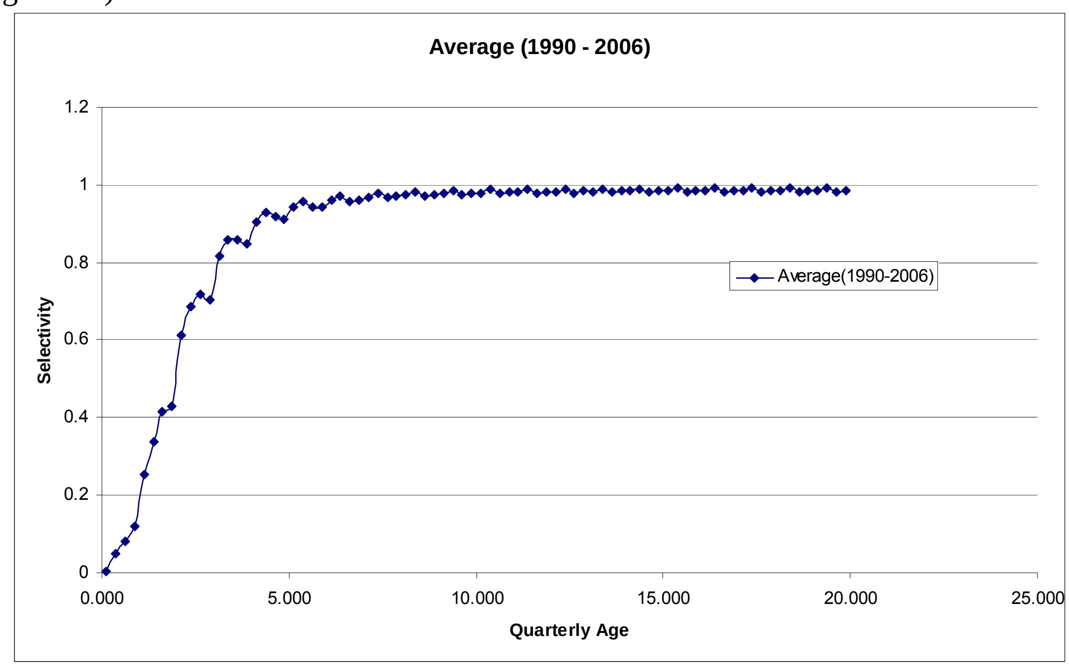

Figure B.1. Selectivity at age (average 1990 – 2006) from SS3 stock scenario 1, a single stock north of the equator (Courtney and Piner 2009b).

Appendix C. Sensitivity Analyses

Sensitivity analyses for Stock Synthesis model runs were conducted for the ISC BILLWG intercessional workshop, Hakodate, Japan April 15-23, 2010, and presented here as an appendix.

Sub-Area 1

The model for Sub-Area 1 was not sensitive to the minor changes made to the model since the preliminary assessment (Models 1 and 2) (Table C.1 and Figure C.1). Changing the block design for Japan Distant Water + Offshore Longline selectivity: Block 1 1951 – 1983; Block 2 1984 - 1993; Block 3 1994 – 2006 (Model 3) improved the fit to CPUE data without affecting the fit to length data (Table C.1 and Figure C.1). Model 3 was not sensitive to iteratively re-weighting sigma r or the effective sample size assigned to CPUE (Sensitivity run 4, and Model 4). The model for Sub-Area 1 was sensitive to assigning weight to CPUE in proportion to catch (Sensitivity run 3), to the weight assigned to the length data (Sensitivity runs 1 and 2), and to iteratively re-weighting the effective sample size assigned to length data (Sensitivity run 5) (Table C.1 and Figure C.1). As a result, the final model for Sub-Area 1 (Model 4) used iteratively re-weighted sigma r and iteratively re-weighted input standard errors for CPUE, but did not use iteratively re-weighted effective sample size for length composition data (Tables 12.1 and C.1; Figure C.1).

Sub-Area 2

Similarly, the model for Sub-Area 2 was not sensitive to the updated catch data or to the minor changes made to the model since the preliminary assessment (Models 1 and 2) (Table C.2 and Figure C.2).

In contrast, the model for Sub-Area 2 was sensitive to minor changes made to the model during the sensitivity analysis conducted here (Table C.2, and Figure C.2). In particular, the sensitivity analyses indicated that model fits to the data for Sub-Area 2 oscillated between two states: 1) a state with relatively high stock biomass and low exploitation rates (e.g., sensitivity runs 1, 7, 8, 11, 14, and model 4); and 2) a state with relatively lower stock biomass and relatively higher exploitation rates (the remainder of the runs) (Table C.2, and Figure C.2). Model fits were particularly sensitive to the very small input standard errors from Chinese Taipei Distant Water Longline standardized CPUE in recent years. When the effect of these small standard errors was reduced (sensitivity runs 1, 7, 8, 11, 14, and model 4), residual plots of fits to Japan Offshore + Distant Water Longline standardized CPUE showed reduced autocorrelation with little effect to fits for Chinese Taipei Distant Water Longline standardized CPUE (not shown). For this reason, model 4 was chosen as the final model for Sub-Area 2. As a result, the final model for Sub-Area 2 (Model 4) used iteratively re-weighted sigma r, but did not use iteratively re-weighted input standard errors for CPUE, and did not use iteratively re-weighted effective sample size for length composition data (Tables 12.2, C.2, and Figure C.1).

All model runs for Sub-Area 2 resulted in estimated ending year female spawning stock biomass in 2006 above female spawning stock biomass at MSY (S_2006/S_MSY>1) (Figure C.2). However, some runs, (e.g., sensitivity run-12 which was equivalent to the final model for Sub-Area 1) resulted in ending year female spawning stock biomass (S_2006/S_MSY) close to female spawning stock biomass at MSY (S/S_MSY =1)((Figure C.2).

The sensitivity analysis conducted here suggests that model results for Sub-Area 2 should be treated with caution. On the one hand, incomplete or inaccurate data can result in a lack of informative signal in fishery data, which can lead to unstable fits like those observed in the sensitivity analysis conducted here. In this regard, model stability for Sub-Area 2 might be improved by a more critical evaluation of all available fishery data by gear type, country, and spatial area including southeastern Pacific Ocean waters south of 20^{o} S (e.g., Hinton and Maunder 2006). On the other hand, very low exploitation rates can also result in a lack of informative signal in the fishery data. As a consequence, if exploitation rates for swordfish in Sub-Area 2 truly are low (sensitivity runs 1, 7, 8, 11, 14, and model 4), then we should also be skeptical of the patterns of recruitment and abundance reported by the model because model fits are unstable (e.g., also see Kleiber and Yokawa 2004).

References

Hinton, M.G., and M. N. Maunder 2006. Status of the swordfish stock in the southeastern Pacific Ocean. Inter.-Amer. Trop. Tuna Comm. Stock Assessment Report 7: 249-282. IATTC Document SAR-7-07d.

Kleiber, P., and K. Yokawa. 2004. MULTIFAN-CL assessment of swordfish in the North Pacific. Working Paper. ISC Swordfish Working Group, January 29 and 31, 2004. ISC/04/SWO-WG/07.

Table C.1. Sensitivity analyses Sub-Area 1.

Model	Run	Details
Preliminary Assessment		(Courtney and Piner 2009c)
Model 1	1	Changed spawning quarter from Q1 to Q2
Model 2	2	Changed block design so that 2006 is now the base year for projections
Sensitivity Run 1	3	Model-2 with added weight to CPUE proportional to catch (mt) from Japan, Chinese Taipei, and Hawaii during the years 1990-2007 (relative to a maximum of 1); and down-weighted effective sample size on length by 1/00*(model estimated R.M.S.E.)
Sensitivity Run 2	4	Model-2 with down-weighted effective sample size on length by 1/00*(model estimated R.M.S.E.)
Sensitivity Run 3	5	Model-2 with added weight to CPUE proportional to catch (mt) from Japan, Chinese Taipei, and Hawaii during the years 1990-2007 (relative to a maximum of 1)
Model 3	6	Model-2 with changed block design for Japan Distant Water + Offshore Longline selectivity: Block 1 1951 – 1983; Block 2 1984 - 1993; Block 3 1994 – 2006
Sensitivity Run 4	6.1	Model-3 with sigma r = 0.6; effective sample size CPUE = Input s.e.; and effective sample size length = Input square root (n)
Model-4 (Final model Sub-Area 1)	6.2	Model-3 with sigma r = model estimated (R.M.S.E.); effective sample size CPUE = model estimated (R.M.S.E.); and effective sample size length = Input square root (n)
Sensitivity Run 5	6.3	Model-3 with sigma r = model estimated (R.M.S.E); effective sample size CPUE = model estimated (R.M.S.E.); and effective sample size length = model estimated mean effective sample size

Table C.2. Sensitivity analyses Sub-Area 2.

Model	Run	Details
Preliminary Assessment		(Courtney and Piner 2009c)
Preliminary Assessment with Updated Catch		(Courtney and Piner 2009c) with updated catch from this report (Appendix B)
Model 1	1	Changed spawning quarter from Q1 to Q2
Model 2	2	Changed block design so that 2006 is now the base year for projections
Sensitivity Run 1	3	Model-2 with added weight to CPUE proportional to catch (mt) from Japan, Chinese Taipei, and Hawaii during the years 1990-2007 (relative to a maximum of 1); and down-weighted effective sample size on length by 1/00*(model estimated R.M.S.E.)
Sensitivity Run 2	4	Model-2 with down weighted effective sample size on length by 1/00*(model estimated R.M.S.E.)
Sensitivity Run 3	5	Model-2 with added weight to CPUE proportional to catch (mt) from Japan, Chinese Taipei, and Hawaii during the years 1990-2007 (relative to a maximum of 1)
Model 3	6	Model-2 with changed block design for Japan Distant Water + Offshore Longline selectivity: Block 1 1951 – 1983; Block 2 1984 - 1993; Block 3 1994 – 2006
Sensitivity Run 4	7	Model-2 with changed block design for Japan Distant Water + Offshore Longline selectivity: Block 1 1951 – 1994; Block 2 1995 – 2006
Sensitivity Run 5	8	Model-2 with down-weighted effective sample size on length by 1/00*(model estimated R.M.S.E.); and changed block design for Japan Distant Water + Offshore Longline selectivity: Block 1 1951 – 1994; Block 2 1995 – 2006
Sensitivity Run 6	9	Model-2 with changed block design for Japan Distant Water + Offshore Longline selectivity: Block 1 1951 – 1983; Block 2 1984 - 1997; Block 3 1998 – 2006
Sensitivity Run 7	10	Model-3 CV Chinese Taipei CPUE = 0.20 for last 5 years
Sensitivity Run 8	2.1	Model-2 with sigma r = 0.6; effective sample size CPUE = Input s.e.; and effective sample size length = Input square root (n)
Sensitivity Run 9	2.2	Model-2 with sigma r = model estimated (R.M.S.E.); effective sample size CPUE = model estimated (R.M.S.E.); and effective sample size length = Input square root (n)
Sensitivity Run 10	2.3	Model-2 with sigma r = model estimated (R.M.S.E.); effective sample size CPUE = model estimated (R.M.S.E.); and effective sample size length = model estimated mean effective sample size
Sensitivity Run 11	6.1	Model-3 with sigma r = 0.6; effective sample size CPUE = Input s.e.; and effective sample size length = Input square root (n)
Sensitivity Run 12	6.2	Model-3 with sigma r = model estimated (R.M.S.E.); effective sample size CPUE = model estimated (R.M.S.E.); and effective sample size length = Input square root (n)
Sensitivity Run 13	6.3	Model-3 with sigma r = model estimated (R.M.S.E.); effective sample size CPUE = model estimated (R.M.S.E.); and effective sample size length = model estimated mean effective sample size
Model 4 (Final model Sub-Area 2)	6.4	Model-3 with sigma r = model estimated (R.M.S.E.); effective sample size CPUE = Input s.e.; effective sample size length = Input square root (n).
Sensitivity Run 14	6.5	Model-3 with sigma r = model estimated (R.M.S.E.); effective sample size CPUE = Input s.e.; effective sample size length = Input square root (n); and estimated growth as single sex by manually setting male growth = female growth

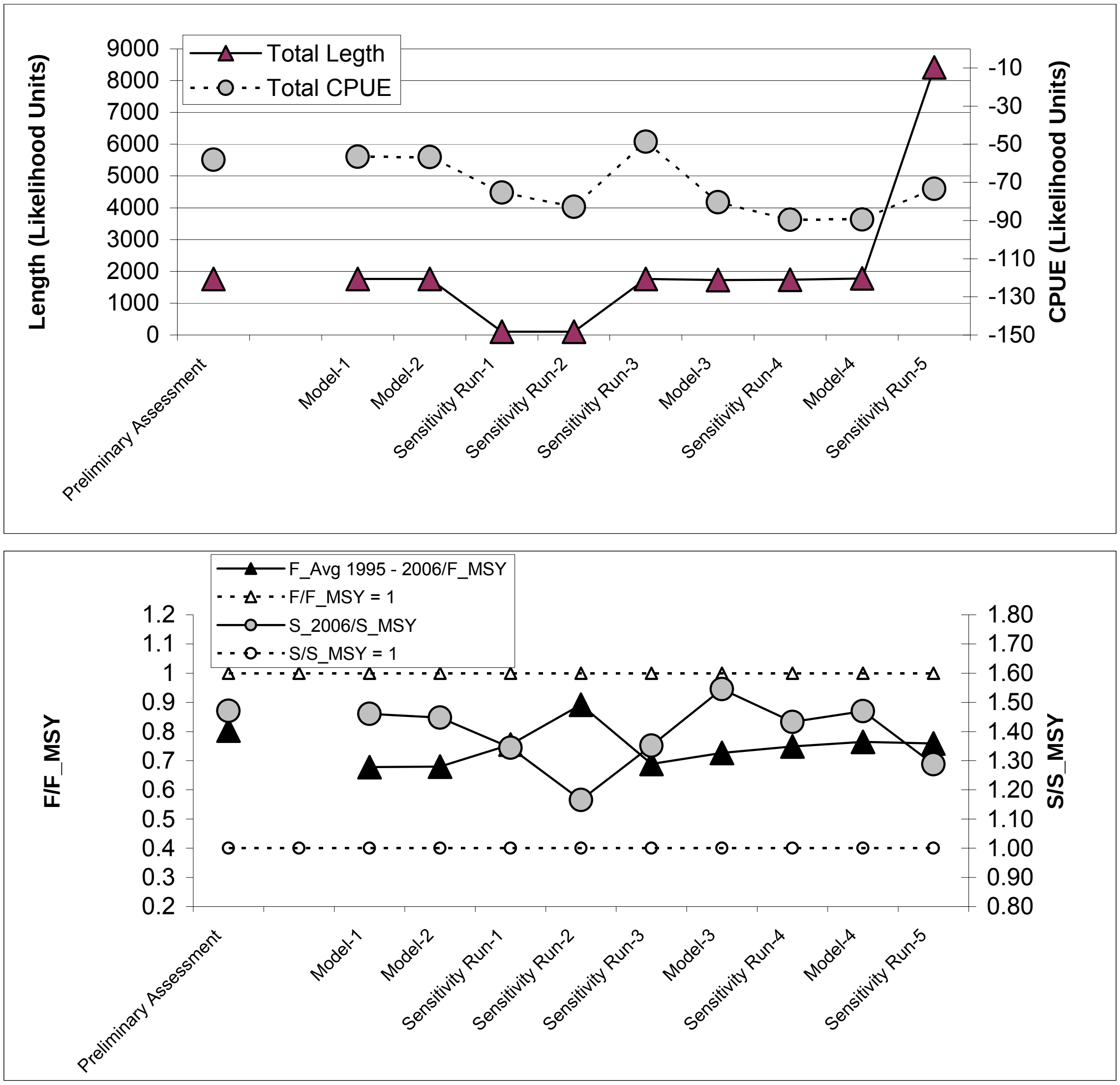

Figure C.1. Sensitivity analyses Sub-Area 1.

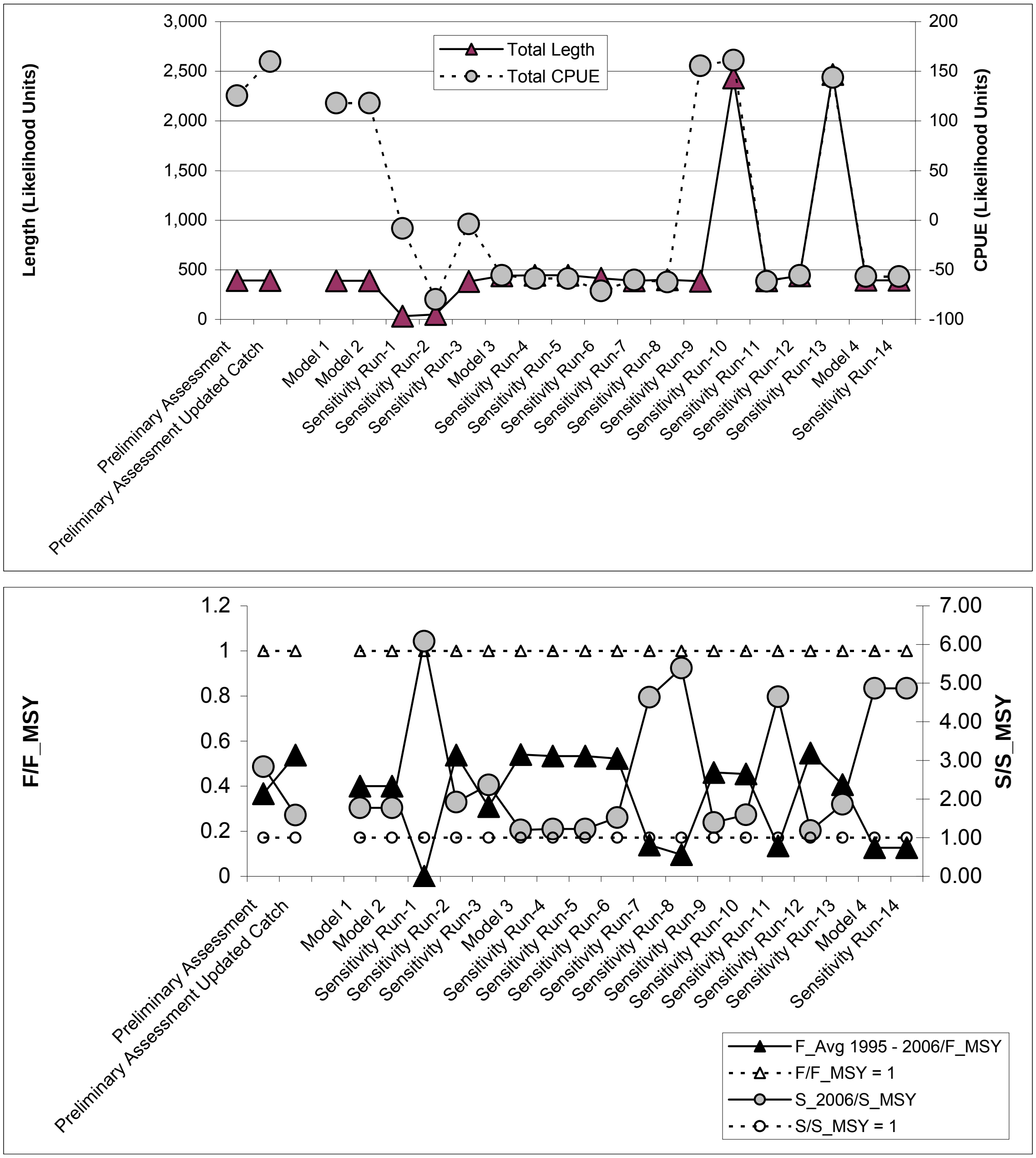

Figure C.2. Sensitivity analyses Sub-Area 2.