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

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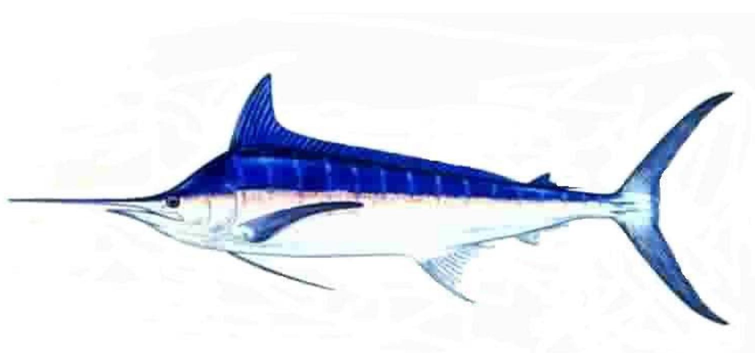

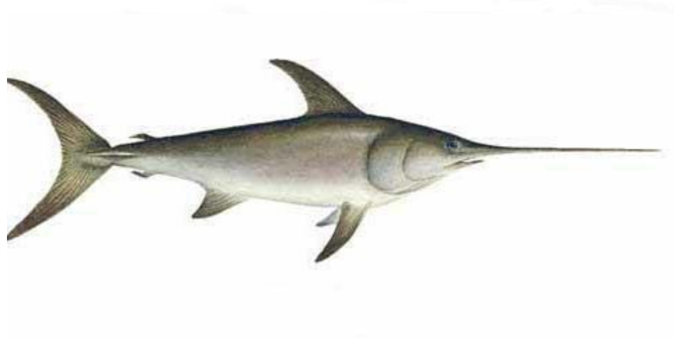

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Preliminary Age Structured Stock Assessment of North Pacific Swordfish (*Xiphias gladius*) with Stock Synthesis under a Two Stock Scenario

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Abstract

This report summarizes Stock Synthesis (SS) model runs for a North Pacific Swordfish (*Xiphias gladius*) stock assessment under a two stock scenario. The stock structure assumed for this assessment was a two-stock scenario (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 1 and 2. Model structure was based on an age-structured stock assessment of North Pacific swordfish under a single stock scenario presented separately. Model results were compared to those from a Bayesian production model fit to the same data. Stock Synthesis models for both Sub-Area 1 and Sub-Area 2 appeared to adequately estimate selectivity for the major fisheries and to fit CPUE series well enough to scale the absolute abundance estimates. The Sub-Area 1 model appeared to adequately fit length compositions from the major fisheries with some caveats. The Sub-Area 2 model had more limited length frequency data and had a relatively poorer fit to the limited length frequency data. Both models estimated ending year 2006 female spawning biomass above spawning biomass at maximum sustainable yield (MSY) and 2006 fishing mortality (F) below F at MSY. Model results from Sub-Area 1 indicated lower biomass and higher harvest rates (often outside 95% Bayesian credible intervals) than a Bayesian surplus production model (BSP) run on the same data. Model results from Sub-Area 1 were most consistent with BSP model results in recent years (1999 – 2006). Model results from Sub-Area 2 were more consistent with BSP but deviated from BSP after 1990.

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 an age-structured stock assessment of North Pacific swordfish under a single stock scenario presented in a separate document (Courtney and Piner 2009a and 2009b). Model results were compared to those from a Bayesian production model fit to the same data (Brodziak and Ishimura 2009, BILL-WG 2009b).

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). 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 4 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) (Figure 3). Length data were compiled separately for Stock Synthesis (Courtney and Fletcher 2009).

For Sub-Area 1, catch for Japan Offshore + Distant Water Longline and U.S. Hawaii Longline 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 and Korea Longline 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, US California Longline, and US California Other + Unknown were assigned to quarter four (Q4) which was consistent with the seasonal timing of swordfish catch (Ito and Childers 2008).

For Sub-Area 2, annual catches for Mexico All Gears (F33) were also assigned to Q4 (Table 7.2). 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 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, quarterly length frequency data were only available for Japan Offshore + Distant Water Longline (F6) (Table 8.2).

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 (S8) were assigned to Q2 based on the proportion of catch in Japan Offshore + Distant Water Longline (F6) 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).

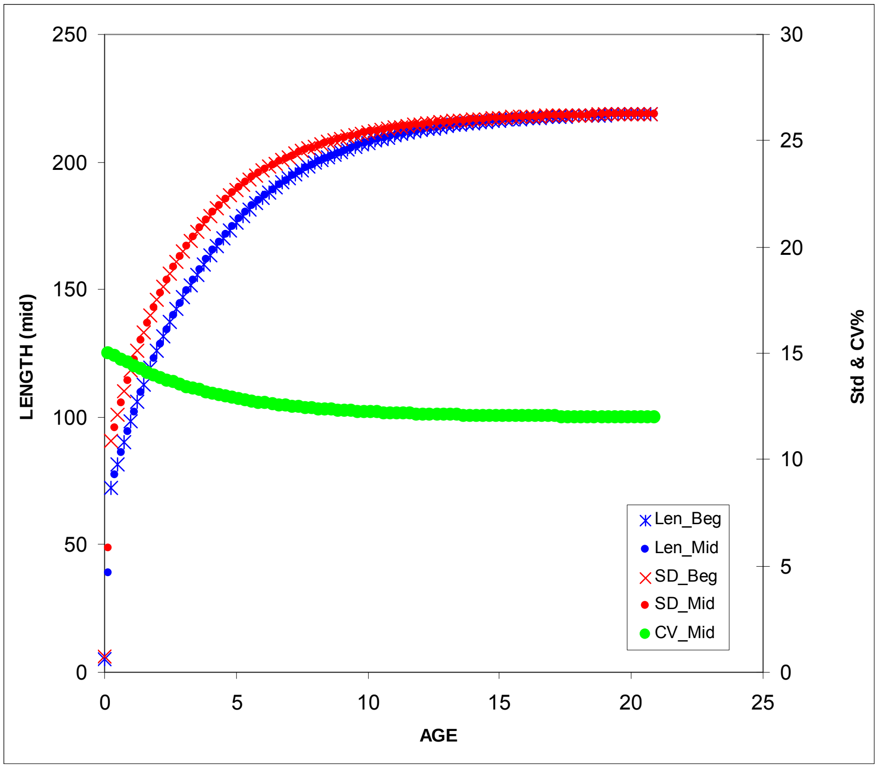
The Sub-Area 1 and Sub-Area 2 models followed the base case model from an age structured stock assessment of North Pacific swordfish under a single stock scenario presented separately (Courtney and Piner 2009a and 2009b).

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.

Recruitment occurred on January 1, no recruitment occurred in other quarters. 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 (Table 9). 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 (F1, F2, F3, F4, F5, F6, F7, F12, F29, and F30) (Table 8). 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, and Mexico All Gears, we assumed that the selectivity patterns mirrored those of Japan Offshore + Distant Water Longline in their respective regions (Table 8). 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) (Table 8).

Selectivity patterns for CPUE time series (S1, S8, S15) mirrored their respective fleet in the region with the highest proportion of catch (Tables 7 and 9).

All selectivity models were 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). The rational for dome-shaped selectivity for Fleet 1 was a relatively larger mode in length of swordfish captured in the same region 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. The rational for including a modified 3 parameter asymptotic double normal model for 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. This may have resulted from not setting parameter bounds correctly to bound within 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 was allowed to vary over two time periods (blocks) for Japan Offshore + Distant Water Longline (start year – 1983, 1984 – 2006) corresponding to a change in target species during the years 1984-1990 (Ishimura et al. 2008) (Table 11). 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).

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).

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).

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 (Table 12). 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.

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 Bayesian production models. Age 2+ total biomass was used as a simple measure of the exploitable biomass because age 2 fish (125.8 cm EFL) 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).

MSY is commonly considered an upper bound for catch rather than a target. Empirical evidence has shown that populations are often exploited at levels higher than MSY before MSY can 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 on estimated quantities were indicative of a non-converged model. The correlation matrix was examined for non-informative parameters. Individual likelihood components were compared for fits to CPUE data (Total, S1, S8, and S15), length data (Total, F1, F2, F3, F4, F5, F6, F7, F12, F29, and F30), total recruitment, total objective function, and the total number of parameters estimated. Parameters estimated at a bound were a diagnostic for possible problems with data or the assumed model structure. Fits to CPUE and patterns in Pearson's residuals of fits to length frequency time series 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

The model for Sub-Area 1 took 1 hr and 45 minutes to run. SS model execution could be improved with no loss of accuracy by combining the catch of all fisheries that share the same selectivity pattern (Table 8.1). Similarly, SS model execution could be improved with no loss of accuracy by assigning CPUE to a fishing fleet with length data rather than modeling CPUE as a mirrored fleet. The model for Sub-Area 2 with fewer fleets took 8 minutes to run.

For Sub-Area 1, four parameter estimates were below the threshold (0.01) for uncorrelated parameters: early recruitment deviation in 1961; and size selectivity parameter 5 (initial intercept of the distribution) for F1 (during the years 1951 – 1983 and 1984 – 2006) and F12. Additionally, five model estimated standard deviations (StDev) for selectivity parameter estimates (Parm) resulted in a coefficient of variation (CV = StDev/Parm) greater than 50%: selectivity parameter 2 (ascending width of the distribution) for F1 (during the years 1951 – 1983 and 1984 – 2006); selectivity parameter 4 (descending width of the distribution) for F1 (during the years 1951 – 1983 and 1984 – 2006), and selectivity parameter 6 (final intercept of the distribution) for F1 (during the years during the years 1951 – 1983) (Figure 7.1). These convergence diagnostics suggest that size selectivity for fleet F1 (Japan Offshore + Distant Water Longline in region R1-1) 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).

For Sub-Area 2, one parameter was estimated near an upper bound: selectivity parameter 2 (ascending slope of the distribution) for F6 (Japan Offshore + Distant Water Longline in region R2-1) (during the years 1951 – 1983) (Figure 7.6). The ascending slope of estimated selectivity during the years 1951 – 1983 was near knife edge and increasing selectivity parameter 2 beyond the upper bound would lead to unreasonably steep selectivity.

3.2 Model Fits

For Sub-Area 1, fits to Japan Offshore + Distant Water Longline CPUE showed non-random blocks of positive and negative residuals following the 1980s (Figure 4.1). For Sub-Area 2, fits to Japan Offshore + Distant Water Longline CPUE over-estimated CPUE prior to 1962 and underestimated CPUE after 1998 (Figure 4.2).

For Sub-Area 1, Pearson residuals for fits to length frequency from Japan Offshore + Distant Water Longline in region R1-1 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 fits to length frequency from Japan Offshore + Distant Water Longline in region R1-2 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 (Figures 12.2, and 12.7.1). 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).

For Sub-Area 2, the scale of Pearson residuals for fits to length frequency data was much larger (max 27, F6, Figure 12.6.1) than for Sub-Area 1 (max 9, F1, Figure 12.1) indicating a relatively poorer fit to length frequency data. Model fits to length frequency data from Japan Offshore + Distant Water Longline in region R2-1 underestimated the number of small fish in many year/quarters (Figures 12.6, and 12.7.2). 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) (Figure 12.7.2).

3.3 Estimated Time Series

Sub-Area 1 model estimated time series of total biomass, age 2+ biomass, and female spawning biomass declined from 1951 – 1970, increased to the 1990's, and then declined to the present (Table 13.1, Figures 17 - 19). Sub-Area 2 model estimated time series of total biomass, age 2+ biomass, and female spawning biomass were relatively flat through the 1970s, declined until 1990 and were variable after the 1980's (Table 13.2, 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). Estimation of main recruitment deviations began in 1970 and ended in 2006, consistent with the availability of length frequency data (1970 – 2006). 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.

Sub-Area 2 age-0 recruitment was estimated with more uncertainty (Figure 20.2). This was consistent with the more limited length frequency data available for Sub-Area 2. For both Sub-Area 1 and Sub-Area 2, there was limited data at low population size to estimate the spawner-recruit relationship (Figure 21).

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 – 2006 except 1962 (Table 13.1, Figures 22.1 and 23.1). Sub-Area 1 model estimated fishing mortality (F) was above F_MSY for most years between 1951 and 1970, varied around F_MSY after 1970, and has been below F_MSY since 2001 (Table 14.1, Figures 22.1 and 24.1). Sub-Area 1 model estimated ending female spawning biomass (S_2006) as a proportion of unfished female spawning biomass (S_0) was 30% (Table 17). Sub-Area 1 annual fishing mortality (F - summed over all fleets and quarters) averaged from 1995-2006 (F_Avg) was 0.64 (Table 18). Sub-Area 1 average fishing mortality (F_avg) from 1995-2006 was below the estimated F at MSY (F_MSY = 0.80)

(Table 18). Average fishing mortality (F_avg) from 1995 – 2006 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).

3.4.2 Sub-Area 2

Sub-Area 2 model estimated female spawning biomass was above MSY for all years from 1951 – 2006 (Table 13.2, Figures 22.2 and 23.2). Sub-Area 2 model estimated fishing mortality (F) was below F_MSY for all years (Table 14.2, Figures 22.2 and 24.2). Sub-Area 2 ending female spawning biomass (S_2006) as a proportion of unfished female spawning biomass (S_0) was 54% (Table 17). Sub-Area 2 annual fishing mortality (F - summed over all fleets and quarters) averaged from 1995-2006 (F_Avg) was 0.24 (Table 18). Sub-Area 2 model estimated average fishing mortality (F_avg) from 1995-2006 was below the estimated F at MSY (F_MSY = 0.66) (Table 18). Average fishing mortality (F_avg) from 1995-2006 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).

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).

Sub-Area 1 Stock Synthesis model estimates of exploitable biomass and harvest rate were most consistent with BSP during recent years (~1999 – 2006) (Figures 25.1 and 26.1). The timing is coincident with an increase in the availability of length frequency data from Japan Offshore + Distant Water Longline since 1999. Sensitivity analyses indicated that the single stock model was sensitive to the addition of a time block for the estimation of growth parameters during the years 1999 – 2006 presumably associated with the increased availability of Japan Offshore + Distant Water Longline length frequency data since 1999 (Courtney and Piner 2009b).

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 slightly lower (mostly inside the 95% Bayesian credible intervals) than time-series of exploitable biomass estimated with Bayesian surplus production (BSP) models run on the same data (Table 13.2, Figure 25.2). Sub-Area 2 Stock Synthesis model estimates of exploitable biomass and harvest rate deviated from BSP beginning in 1990 (Figures 25.2 and 26.2). The timing of the deviation in estimated exploitable biomass and harvest rate (~1990) lagged behind the assumed timing of the change in selectivity for the Japan Offshore and Distant Water Longline fleet in Sub-Area 2 after 1983 (Figure 7.1, 7.6) associated with a change in target species during the years 1983 – 1990 (Ishimura et al. 2008).

6. Conclusions

Both Sub-Area 1 and Sub-Area 2 models 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). The Sub-Area 1 model appeared to adequately fit length compositions from the major fisheries (Figures 12 – 16). The Sub-Area 2 model had more limited length frequency data and had a relatively poor fit to the limited length frequency data. Both models estimated ending year 2006 spawning biomass above spawning biomass at maximum sustainable yield (MSY) and 2006 fishing mortality (F) below F at MSY (Figure 22).

Model results from Sub-Area 1 indicated lower biomass and higher harvest rates (often outside 95% Bayesian credible intervals) than a Bayesian surplus production model run on the same data (Figures 23 – 26).

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.

Model results from Sub-Area 1 were most consistent with BSP model results in recent years (~1999 – 2006). Model results from Sub-Area 2 were more consistent with BSP but deviated from BSP after 1990 possibly coincident with a change in time-varying selectivity estimated for Japan Offshore + Distant Water Longline fleet beginning in 1983 (Figures 7.6, 25.2, and 26.2).

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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	$\boxed{EFL_t = EFL_\infty\left(1-e^{-k(t-t_0)}\right)}$ 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 = $1.2988x10^{-5}$ b = 3.0738			$\boxed{W(kg) = aEFL^b}$ 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	$\boxed{p(EFL) = \left(1+\exp\left(\frac{-(EFL-L_{50})}{\sigma_m}\right)\right)^{-1}}$ 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	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 (4) by country and fleet.

Fleet Code	Country	Fleet	Annual Catch	Years	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
F6	Japan	Offshore + Distant Water	y	1954 – 2006	90.49%	54.62%	Y	27.87%	19.49%	23.48%	29.15%
F24	Chinese Taipei	Distant Water	y	1998 – 2006	0.00%	11.01%	Mirror F6	-	-	-	-
F28	Korea	Longline	y	1977 – 2006	0.53%	2.78%	Mirror F6	-	-	-	-
F33	Mexico	All Gears	y	1980 – 2006	8.98%	31.59%	Assign Q4	-	-	-	100.00%

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	1972, 1987, 1988, 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	1970 – 1972, 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.

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
F6	Japan	Offshore + Distant Water	Y	1970 – 1980, 1984, 1986 – 2006	Y	Logistic
F24	Chinese Taipei	Distant Water	N	-	Mirror F6	Mirror F6
F28	Korea	Longline	N	-	Mirror F6	Mirror F6
F33	Mexico	All Gears	N	-	Mirror F6	Mirror F6

[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 Q2	Mirror F6
S8	Chinese Taipei	Distant Water (Sub-Area 2)	Y	1995 – 2006	Assign Q2	Mirror F6

[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).

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	
Effective Sample Size	Iteratively re-weighted for CPUE from input standard error	
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 S8)
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 by country and fleet (Region 2-1)

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

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

[1] Ishimura et al. 2008.
[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
Japan[1]	Offshore + Distant Water	Length Selectivity	1955 – 1983	1984 – 2006

[1] Ishimura et al. 2008.

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	0.424526	0.6	-0.175474

CPUE	Country	Fleet	N	Model Estimate (R.M.S.E)	Mean Input SE	+Var Adj Sub-Area1
S1	**Japan**	Offshore + Distant Water (All Regions)	55	0.23	0.14	0.09
S8	**Chinese Taipei**	Distant Water (All Regions)	12	0.53	0.46	0.07
S15	**US Hawaii**	Longline Shallow-Set	9	0.32	0.15	0.16

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	223.5	61.8	1
F2	**Japan**	Offshore + Distant Water (R1-2)	115	267.5	57.3	1
F3	**Japan**	Offshore + Distant Water (R1-3)	3	100.1	13.7	1
F4	**Japan**	Offshore + Distant Water (R1-4)	78	123.7	16.0	1
F5	**Japan**	Offshore + Distant Water (R1-5)	21	128.6	17.5	1
F7	**Japan**	Driftnet (R1-1)	3	413.0	36.9	1
F12	**Japan**	Other, Primarily Harpoon (R1-1)	1	206.0	22.3	1
F29	**US Hawaii**	Longline (Stratified by Depth)	33	190.7	31.9	1
F30	**US California**	Gillnet (R1-3)	48	144.7	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	0.535098	0.6	-0.064902

CPUE	Country	Fleet	N	Model Estimate (R.M.S.E)	Mean Input SE	+Var Adj Sub-Area 2
S1	**Japan**	Offshore + Distant Water	52	0.32	0.13	0.19
S8	**Chinese Taipei**	Distant Water	12	0.29	0.44	-0.14

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	111	121.2	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	43,230	685	697	11					
1951	20,034	711	429	151	54,585	45,863	58,850	96,300	149,300
1952	19,537	750	539	205	50,927	45,601	48,170	80,600	127,700
1953	18,056	1,131	651	258	46,884	40,216	44,050	74,190	118,300
1954	15,941	1,587	600	243	43,435	35,466	46,060	76,910	122,600
1955	13,856	1,814	647	277	39,393	32,021	44,480	74,210	119,100
1956	12,239	1,876	931	433	36,302	28,417	42,240	70,300	112,200
1957	10,927	1,852	954	479	36,299	24,993	42,920	71,250	113,500
1958	11,251	1,913	812	410	38,906	27,314	47,370	77,460	122,900
1959	10,767	1,813	1,051	501	36,544	26,786	44,000	72,580	115,800
1960	10,522	1,643	848	409	37,351	24,810	44,400	72,910	115,700
1961	9,480	1,377	750	327	33,818	23,783	40,860	69,070	111,700
1962	8,268	1,482	624	259	29,313	20,508	36,610	64,750	107,700
1963	9,398	1,588	587	236	30,950	23,403	39,720	69,230	113,500
1964	10,587	1,687	601	238	32,682	25,567	41,090	70,840	115,300
1965	12,179	1,766	550	215	36,102	28,721	44,890	75,550	121,200
1966	12,499	1,752	548	215	36,187	29,471	44,010	74,130	119,200
1967	12,196	1,692	640	228	35,104	28,413	40,380	68,480	110,000
1968	11,511	1,553	478	162	34,312	26,518	37,650	64,230	103,500
1969	11,217	1,329	320	91	32,729	26,914	37,360	64,080	103,500
1970	11,324	1,138	506	106	30,855	26,913	39,310	66,960	107,300
1971	10,742	976	441	93	30,166	23,943	40,330	68,420	109,800
1972	10,527	946	250	65	29,888	24,487	41,610	70,300	113,200
1973	10,357	992	1,052	128	27,709	24,588	45,370	76,150	121,700
1974	10,442	1,017	710	123	34,334	21,384	48,700	81,300	129,000
1975	12,464	1,039	438	85	40,133	31,415	48,600	81,080	129,100
1976	14,008	1,059	494	72	40,065	34,679	48,270	81,020	129,600
1977	13,750	1,042	479	67	37,606	31,525	44,640	75,690	121,500
1978	12,669	971	512	68	34,882	28,994	43,240	73,110	117,100
1979	10,943	880	586	75	31,505	25,225	43,970	74,990	120,600
1980	10,280	801	610	76	30,949	23,789	47,770	81,050	130,300
1981	10,750	746	579	72	32,969	25,460	49,360	83,100	133,400
1982	11,316	701	470	64	34,198	27,063	50,930	85,640	137,600
1983	11,918	652	873	70	34,283	28,479	57,410	96,370	154,400
1984	11,676	598	980	72	36,751	26,021	58,710	99,360	159,800
1985	12,395	577	493	56	41,548	29,589	64,140	109,400	177,200
1986	13,150	584	690	51	39,687	33,670	63,330	109,700	178,900
1987	13,540	605	546	49	39,722	31,279	66,050	113,400	185,200
1988	13,028	620	854	58	37,571	30,867	63,550	109,100	178,200
1989	13,007	637	718	59	40,009	29,518	59,140	101,000	163,900
1990	14,087	663	540	53	42,883	34,034	60,230	101,900	164,500
1991	15,120	675	956	62	43,119	36,434	57,820	97,430	156,600
1992	15,596	666	1,116	71	46,631	34,867	57,900	96,930	155,400
1993	15,420	660	665	63	49,725	36,106	52,160	88,420	142,800
1994	15,830	688	648	58	47,793	39,691	42,510	73,310	119,300
1995	16,555	721	731	60	46,983	39,032	36,260	61,920	100,500
1996	16,673	724	710	55	47,183	38,207	34,510	58,290	93,940
1997	16,814	710	249	37	47,787	39,063	31,980	53,500	86,040
1998	16,131	685	1,052	58	41,931	38,821	31,650	53,260	85,370
1999	14,774	660	853	64	43,767	30,845	35,530	59,370	94,850
2000	14,772	675	391	50	46,105	35,658	40,330	67,080	106,800
2001	15,008	735	484	50	42,265	37,464	42,460	72,060	116,300
2002	15,133	798	533	56	40,353	34,386	43,170	72,620	116,400
2003	14,189	836	624	73	38,486	31,914	40,480	68,050	108,600
2004	13,157	898	683	83	37,600	29,927	40,650	68,040	108,500
2005	13,025	1,062	357	57	38,602	30,236	41,960	69,980	111,300
2006	12,911	1,359	273	61	35,738	31,373	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	17,713	1,998	285	32					
1955	17,713	1,998	213	85	41,893	38,318	8,859	21,610	41,820
1956	17,618	1,989	205	81	40,983	38,308	8,810	20,780	40,060
1957	17,237	1,979	200	79	39,555	36,990	13,470	29,210	54,060
1958	16,541	1,990	212	86	37,778	35,272	12,380	27,130	50,650
1959	15,759	1,988	247	103	36,213	33,549	10,570	23,990	45,950
1960	15,114	1,961	293	127	35,337	32,235	12,230	27,330	51,790
1961	14,793	1,952	315	139	35,471	31,797	16,530	35,650	66,030
1962	14,786	2,006	302	133	36,153	32,215	20,130	42,990	79,170
1963	15,026	2,125	278	120	36,848	33,065	22,820	48,400	89,190
1964	15,170	2,248	262	111	36,861	33,395	22,990	49,370	91,230
1965	15,189	2,313	267	114	36,520	33,238	21,840	47,670	89,140
1966	15,290	2,306	304	134	36,582	33,245	22,790	49,470	91,910
1967	15,202	2,255	418	177	36,739	32,928	22,720	49,750	92,850
1968	15,445	2,236	371	146	38,656	33,433	24,580	53,030	98,380
1969	16,069	2,336	290	97	40,435	35,812	27,820	59,260	109,100
1970	15,911	2,491	333	101	39,187	35,588	28,290	61,240	113,900
1971	16,005	2,588	305	99	39,146	34,989	25,050	55,110	102,900
1972	16,352	2,654	248	102	39,696	35,883	24,330	53,690	100,300
1973	16,380	2,705	249	118	39,063	35,967	26,330	56,890	105,500
1974	15,700	2,721	232	122	37,133	34,031	26,170	57,110	106,200
1975	15,236	2,685	395	154	35,870	32,967	26,080	56,570	105,300
1976	14,793	2,657	296	124	36,427	31,501	25,560	55,150	102,400
1977	14,694	2,698	312	111	36,425	32,737	25,490	54,940	101,400
1978	14,722	2,776	176	80	36,379	32,500	22,670	49,270	92,200
1979	14,764	2,825	257	114	35,033	32,835	20,790	45,460	84,900
1980	14,452	2,771	197	97	34,180	30,982	20,000	43,500	81,030
1981	13,686	2,629	216	104	32,178	29,732	17,990	39,280	73,390
1982	12,396	2,451	160	74	29,411	26,748	15,970	35,350	66,690
1983	11,364	2,270	160	74	26,761	24,780	14,830	33,260	62,830
1984	10,728	2,113	653	176	25,193	23,170	12,260	28,150	54,320
1985	10,890	2,011	276	121	30,279	22,134	13,650	30,550	58,180
1986	12,456	2,047	164	62	33,511	30,065	16,830	36,340	67,440
1987	13,671	2,119	143	55	33,488	31,448	18,720	40,020	74,060
1988	13,559	2,077	190	67	31,195	29,408	17,310	37,430	69,800
1989	12,390	1,909	213	70	28,582	26,212	17,180	37,080	68,870
1990	11,160	1,729	200	61	26,505	23,849	18,070	38,280	70,550
1991	9,264	1,581	192	61	22,687	20,235	15,780	34,820	65,500
1992	8,531	1,488	227	74	21,197	18,808	16,160	34,950	65,450
1993	7,624	1,426	370	94	19,592	16,781	15,890	34,820	65,300
1994	7,513	1,424	300	94	21,034	16,460	15,620	34,220	64,260
1995	8,249	1,505	311	93	23,041	19,315	16,680	36,310	67,440
1996	9,423	1,625	280	88	25,541	21,667	20,780	44,330	81,470
1997	10,475	1,727	278	84	27,346	23,855	25,570	52,810	95,500
1998	10,244	1,787	238	87	26,403	22,983	24,850	52,470	96,500
1999	9,207	1,838	542	140	23,618	20,694	22,550	50,020	93,800
2000	9,750	1,954	521	80	27,626	20,898	29,340	62,330	114,000
2001	10,725	2,243	103	39	31,404	25,000	33,770	71,860	131,800
2002	11,677	2,574	157	27	29,900	28,625	31,530	68,820	127,300
2003	11,428	2,669	336	52	27,015	25,065	29,980	65,170	120,500
2004	10,470	2,535	74	28	26,069	21,915	28,080	60,830	113,300
2005	9,972	2,380	300	57	23,837	22,903	25,700	56,080	105,200
2006	9,645	2,241	193	92	24,038	20,308	27,680	59,740	111,100

[1] (BILL-WG 2009b).

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	1.03	0.145	0.25	0.078	0.13	0.198
1952	0.82	0.096	0.26	0.092	0.15	0.243
1953	0.70	0.069	0.31	0.105	0.18	0.282
1954	0.75	0.090	0.38	0.111	0.19	0.295
1955	0.88	0.128	0.44	0.118	0.20	0.317
1956	1.13	0.198	0.54	0.138	0.23	0.367
1957	1.27	0.250	0.61	0.134	0.23	0.353
1958	1.74	0.350	0.72	0.160	0.27	0.415
1959	1.65	0.282	0.70	0.162	0.27	0.425
1960	2.32	0.294	0.88	0.190	0.32	0.494
1961	2.77	0.310	0.89	0.189	0.33	0.516
1962	2.11	0.378	0.58	0.111	0.20	0.325
1963	1.09	0.200	0.44	0.091	0.16	0.259
1964	0.89	0.175	0.31	0.068	0.12	0.190
1965	1.24	0.250	0.37	0.087	0.15	0.235
1966	1.15	0.219	0.38	0.094	0.16	0.254
1967	0.92	0.146	0.41	0.107	0.18	0.291
1968	1.15	0.207	0.42	0.108	0.19	0.297
1969	1.05	0.193	0.32	0.084	0.15	0.233
1970	1.13	0.191	0.32	0.081	0.14	0.222
1971	0.61	0.063	0.33	0.071	0.12	0.193
1972	0.52	0.052	0.30	0.064	0.11	0.175
1973	0.54	0.057	0.30	0.061	0.10	0.163
1974	0.59	0.062	0.39	0.064	0.11	0.170
1975	0.71	0.081	0.34	0.083	0.14	0.222
1976	0.78	0.091	0.34	0.091	0.16	0.244
1977	0.69	0.066	0.35	0.091	0.16	0.246
1978	0.87	0.088	0.42	0.105	0.18	0.285
1979	0.71	0.062	0.42	0.087	0.15	0.238
1980	0.83	0.082	0.38	0.069	0.12	0.188
1981	0.73	0.070	0.39	0.074	0.13	0.199
1982	0.65	0.049	0.35	0.068	0.12	0.185
1983	0.74	0.051	0.40	0.074	0.13	0.198
1984	0.84	0.061	0.49	0.079	0.14	0.216
1985	0.96	0.065	0.51	0.085	0.15	0.234
1986	0.77	0.050	0.38	0.072	0.13	0.203
1987	0.71	0.045	0.42	0.070	0.12	0.198
1988	0.67	0.044	0.37	0.065	0.11	0.182
1989	0.67	0.042	0.37	0.067	0.12	0.185
1990	0.58	0.036	0.33	0.068	0.12	0.185
1991	0.56	0.030	0.32	0.074	0.13	0.200
1992	0.80	0.043	0.46	0.104	0.18	0.279
1993	0.87	0.048	0.48	0.122	0.21	0.335
1994	0.69	0.037	0.35	0.115	0.20	0.323
1995	0.65	0.035	0.32	0.124	0.22	0.344
1996	0.65	0.040	0.31	0.125	0.22	0.341
1997	0.61	0.029	0.32	0.146	0.25	0.392
1998	0.68	0.035	0.32	0.144	0.25	0.388
1999	0.77	0.039	0.43	0.138	0.24	0.370
2000	0.79	0.043	0.40	0.135	0.23	0.357
2001	0.52	0.027	0.28	0.090	0.15	0.245
2002	0.53	0.031	0.30	0.088	0.15	0.237
2003	0.57	0.038	0.34	0.099	0.17	0.264
2004	0.59	0.044	0.35	0.096	0.16	0.256
2005	0.61	0.057	0.36	0.098	0.17	0.260
2006	0.70	0.089	0.38	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	0.002	0.00	0.008
1958	0.00	0.000	0.00	0.001	0.00	0.006
1959	0.00	0.000	0.00	0.001	0.00	0.006
1960	0.01	0.001	0.00	0.002	0.00	0.008
1961	0.02	0.003	0.01	0.007	0.01	0.027
1962	0.04	0.005	0.02	0.010	0.02	0.038
1963	0.07	0.008	0.04	0.015	0.03	0.057
1964	0.07	0.009	0.04	0.015	0.03	0.061
1965	0.04	0.005	0.02	0.009	0.02	0.037
1966	0.06	0.007	0.03	0.012	0.03	0.049
1967	0.05	0.006	0.03	0.010	0.02	0.042
1968	0.06	0.008	0.04	0.013	0.03	0.051
1969	0.17	0.023	0.10	0.032	0.07	0.125
1970	0.12	0.017	0.07	0.021	0.04	0.084
1971	0.06	0.009	0.04	0.012	0.03	0.050
1972	0.07	0.010	0.04	0.015	0.03	0.061
1973	0.12	0.018	0.07	0.023	0.05	0.092
1974	0.07	0.011	0.04	0.013	0.03	0.052
1975	0.08	0.012	0.05	0.014	0.03	0.057
1976	0.10	0.016	0.06	0.019	0.04	0.074
1977	0.11	0.019	0.07	0.021	0.04	0.085
1978	0.10	0.016	0.06	0.020	0.04	0.080
1979	0.08	0.013	0.04	0.017	0.04	0.071
1980	0.11	0.019	0.06	0.025	0.05	0.100
1981	0.18	0.030	0.10	0.041	0.09	0.166
1982	0.16	0.028	0.09	0.037	0.08	0.156
1983	0.10	0.017	0.06	0.023	0.05	0.096
1984	0.06	0.011	0.04	0.017	0.04	0.073
1985	0.06	0.010	0.04	0.017	0.04	0.072
1986	0.10	0.015	0.06	0.029	0.06	0.115
1987	0.13	0.017	0.08	0.033	0.07	0.130
1988	0.14	0.019	0.08	0.036	0.08	0.144
1989	0.15	0.020	0.09	0.035	0.07	0.140
1990	0.33	0.047	0.19	0.065	0.14	0.255
1991	0.22	0.034	0.13	0.042	0.09	0.173
1992	0.33	0.053	0.20	0.056	0.12	0.229
1993	0.28	0.047	0.17	0.045	0.10	0.184
1994	0.23	0.038	0.16	0.040	0.09	0.163
1995	0.17	0.027	0.11	0.031	0.07	0.127
1996	0.16	0.024	0.10	0.027	0.06	0.105
1997	0.31	0.046	0.19	0.048	0.10	0.178
1998	0.42	0.071	0.25	0.061	0.13	0.235
1999	0.19	0.034	0.12	0.027	0.06	0.111
2000	0.28	0.053	0.20	0.037	0.08	0.143
2001	0.30	0.061	0.20	0.037	0.08	0.144
2002	0.27	0.057	0.15	0.035	0.07	0.140
2003	0.25	0.054	0.15	0.031	0.07	0.125
2004	0.19	0.042	0.12	0.023	0.05	0.094
2005	0.15	0.031	0.09	0.019	0.04	0.076
2006	0.20	0.044	0.13	0.016	0.03	0.063

[1] (BILLWG 2009b).

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.

	Total (S)	S1	S8	S15	Total Recruitment	Total Obj Fun	# Parameters
Sub-Area 1	-58.1	-48.1	-5.6	-4.4	-19.0	1,689.2	107

Table 15.2. Sub-Area 2 Stock Synthesis model results for individual likelihood component fits to CPUE data (Total, S1 and S8) total recruitment, and total objective function, along with the total number of estimated parameters.

	Total (S)	S1	S8	Total Recruitment	Total Obj Fun	# Parameters
Sub-Area 2	125.6	-31.6	157.2	-12.7	505.1	67

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).

	Total	F1	F2	F3	F4	F5	F7	F12	F29	F30
Sub-Area 1	1,764.2	725.4	507.2	6.4	170.8	52.8	5.6	1.4	108.2	186.5

Table 16.2. Sub-Area 2 Stock Synthesis model results for individual likelihood component fits to length data (Total and F6).

	Total	F6
Sub-Area 2	392.2	392.2

Table 17. Sub-Area 1 and Sub-Area 2 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	43,230	54,585	1.47	30%	39%	65%	68%
Sub-Area 2	17,713	41,893	2.84	54%	68%	57%	53%

Table 18. Sub-Area 1 and 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 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	12,325	0.80	0.036	1.10	0.064	2.77	0.90	0.64	0.80
Sub-Area 2	5,050	0.66	0.027	NA	NA	0.42	0.13	0.24	0.37

Figures

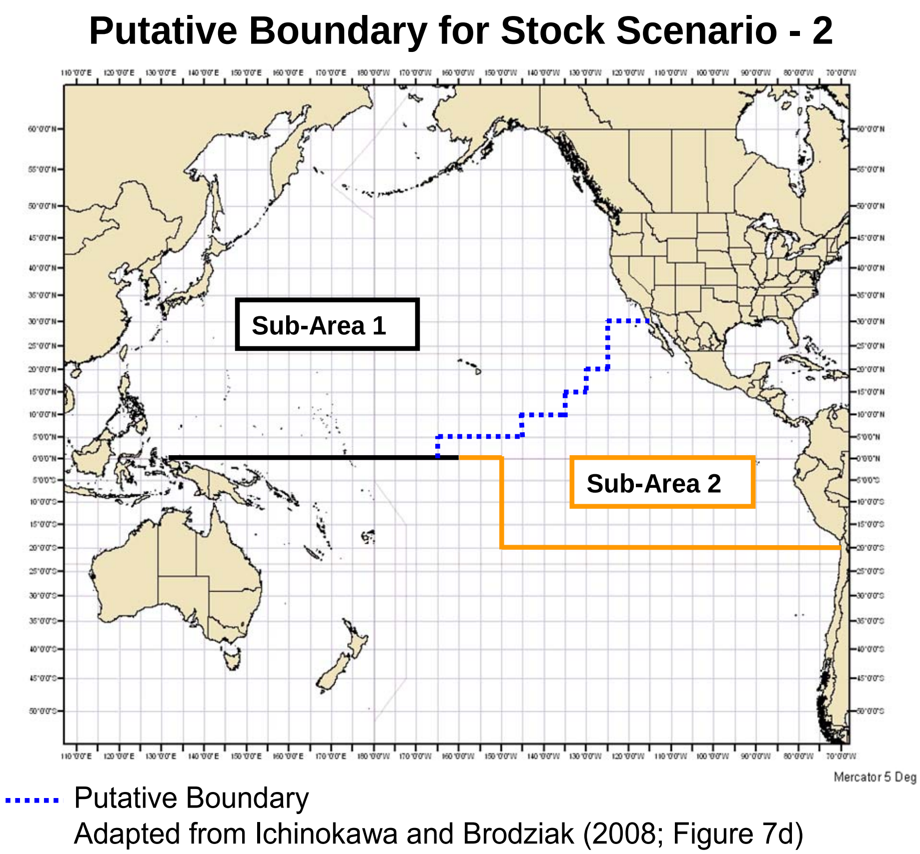

Figure 1. Stock Scenario-2, two North Pacific swordfish stocks north of the equator (BILL-WG 2008, BILL-WG 2009a, BILL-WG 2009b).

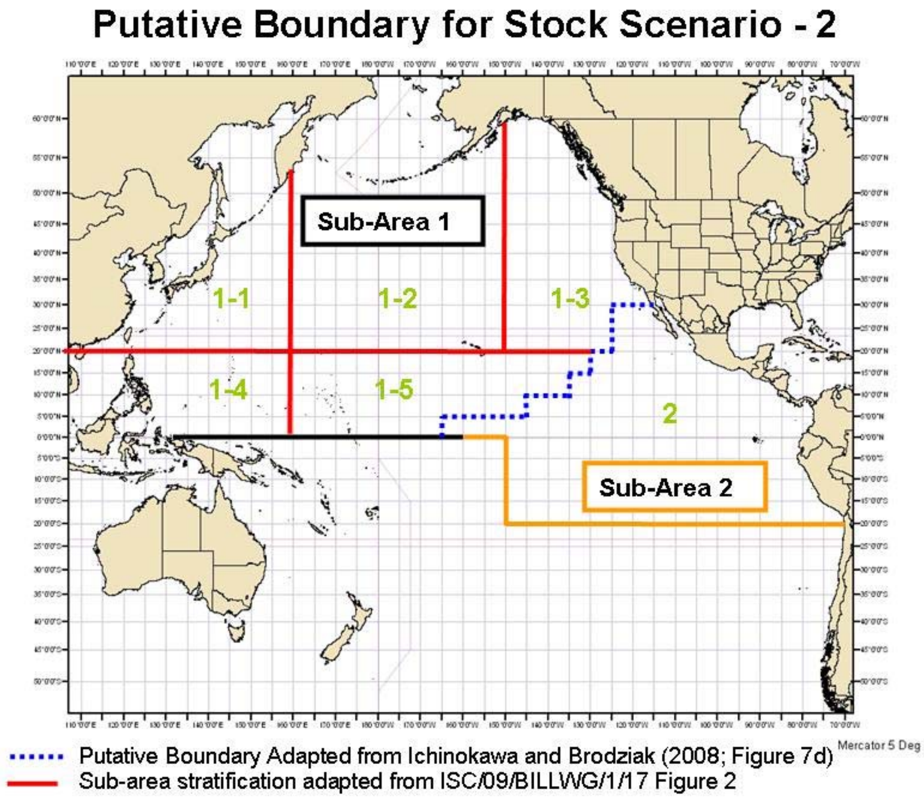

Figure 2. Regional stratification under Stock Scenario-2 (BILL-WG 2009a, BILL-WG 2009b).

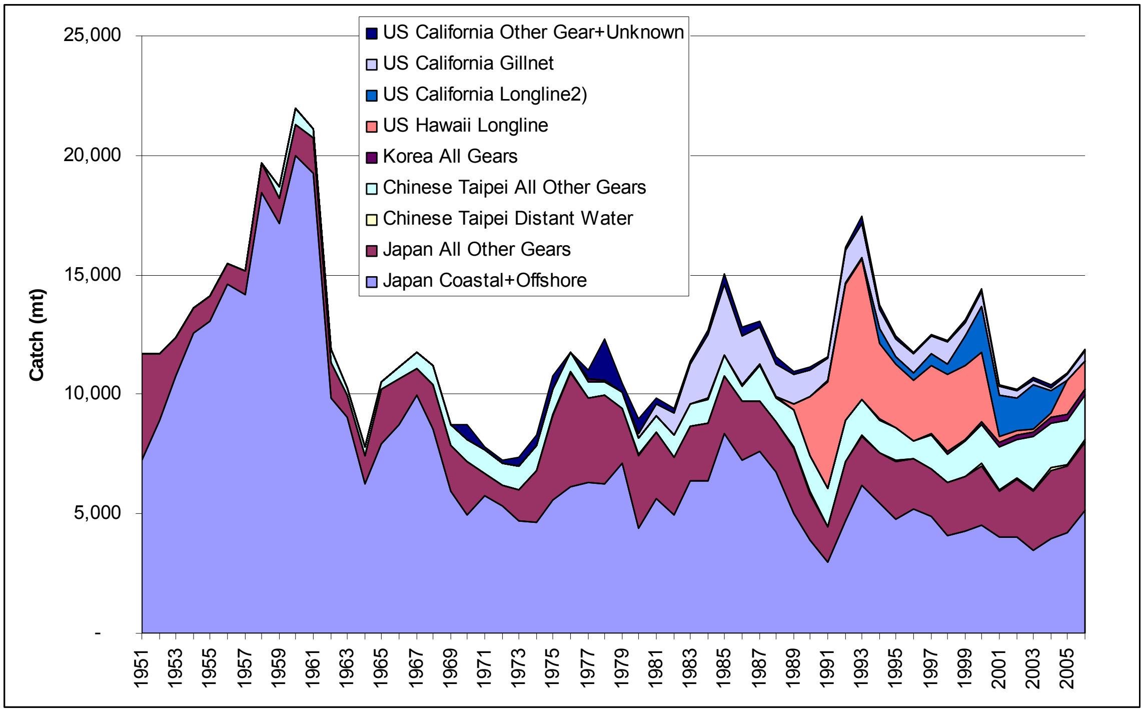

Figure 3.1. Sub-Area 1 annual catch of swordfish (mt) by fleet (Courtney and Wagatsuma 2009).

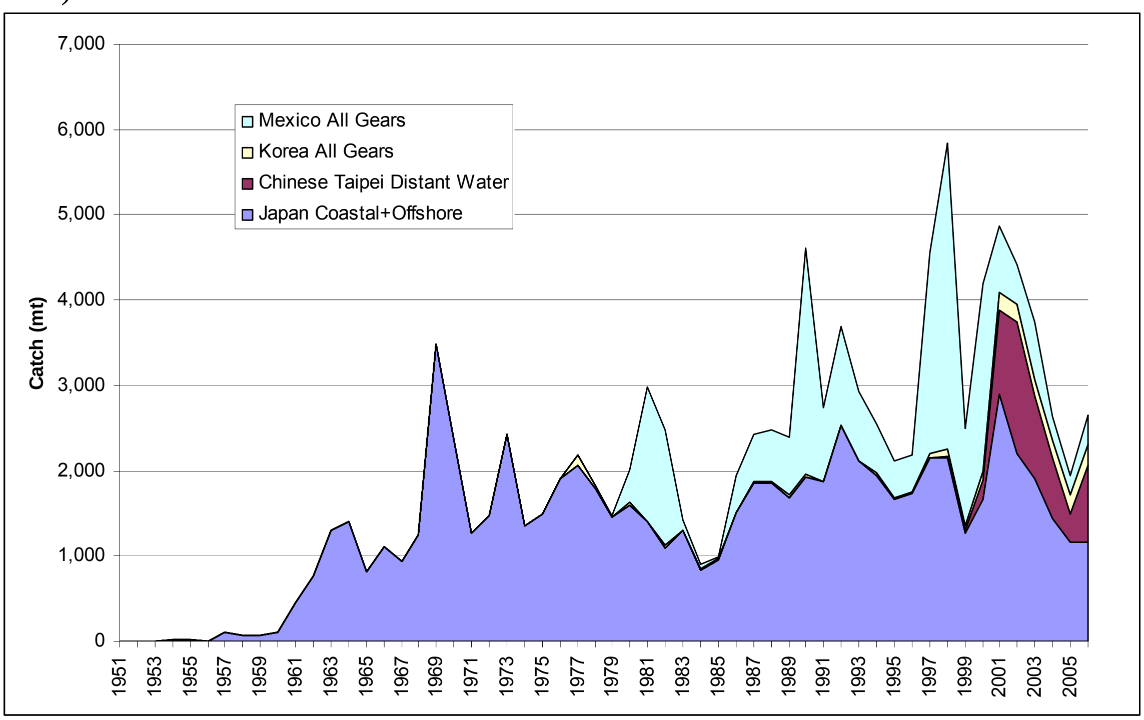

Figure 3.2. Sub-Area 2 annual catch of swordfish (mt) by fleet (Courtney and Wagatsuma 2009).

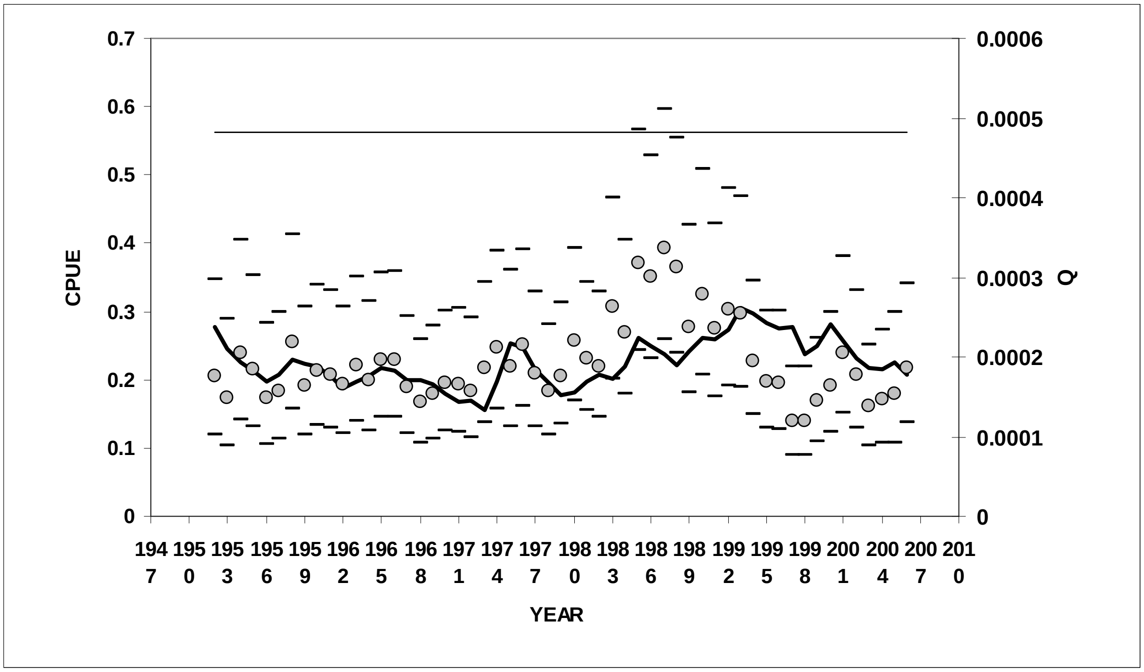

Figure 4.1. Sub-Area 1 Stock Synthesis model fit to standardized CPUE time series (S1) Japan Offshore + Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(observed se), and thin line is effective q.

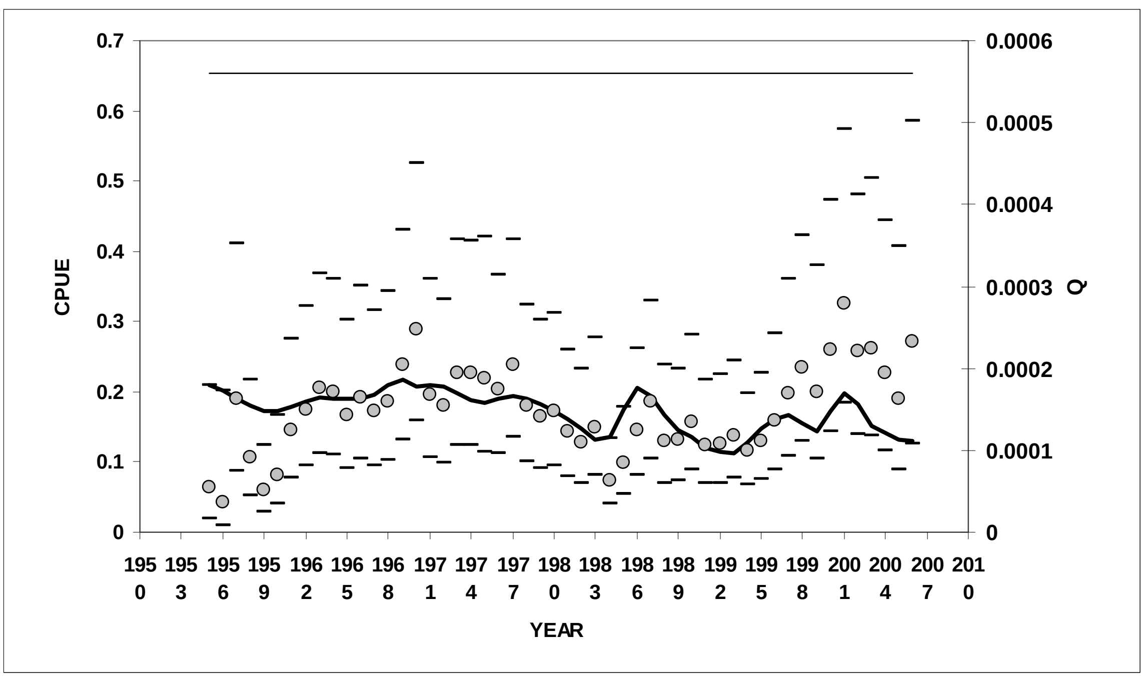

Figure 4.2. Sub-Area 2 Stock Synthesis model fit standardized CPUE time series (S1) Japan Offshore + Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(observed se), and thin line is effective q.

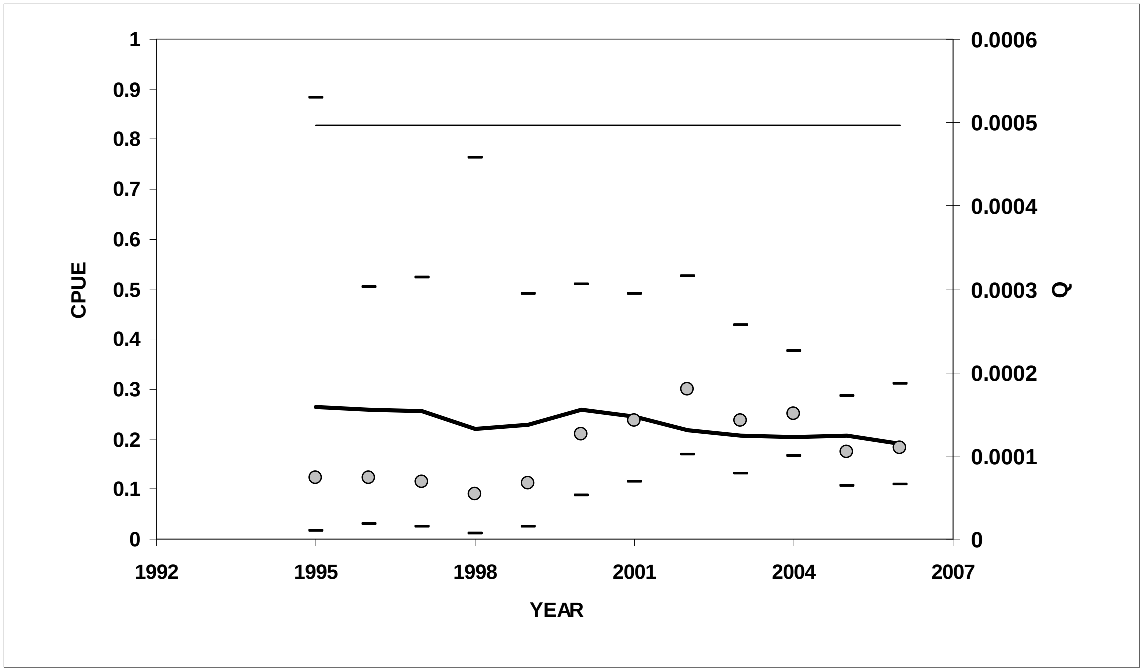

Figure 5.1. Sub-Area 1 fit to Standardized CPUE time series (S8) Chinese Taipei Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(observed se), and thin line is effective q.

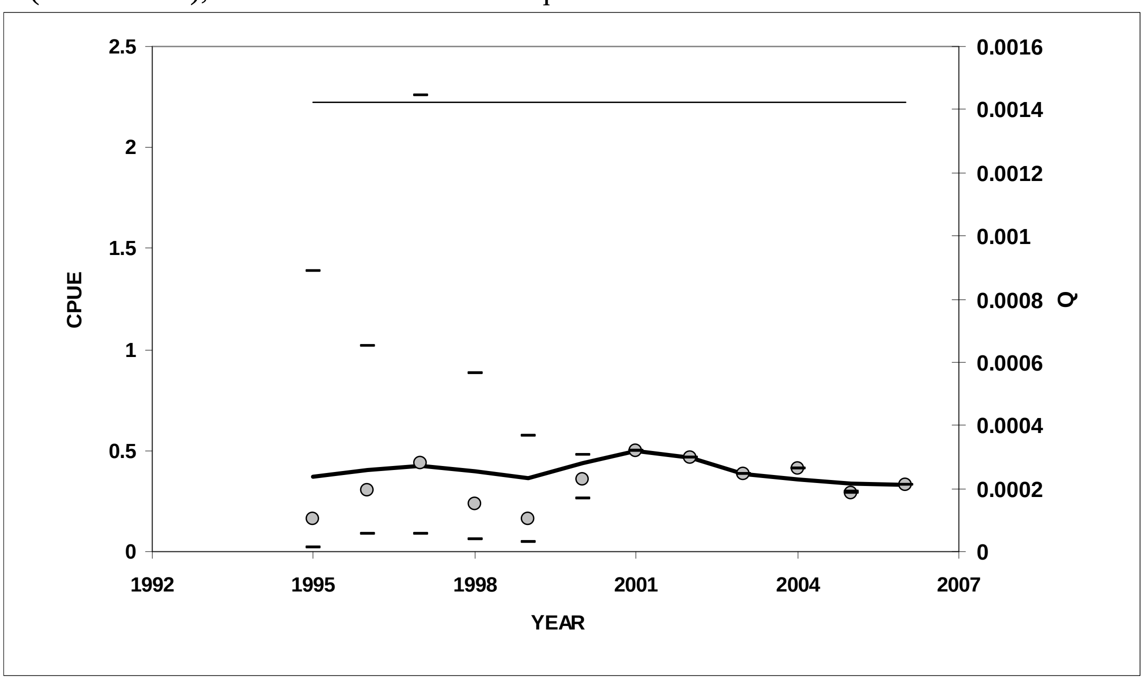

Figure 5.2. Sub-Area 2 fit to Standardized CPUE time series (S8) Chinese Taipei Distant Water Longline. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(observed se), and thin line is effective q.

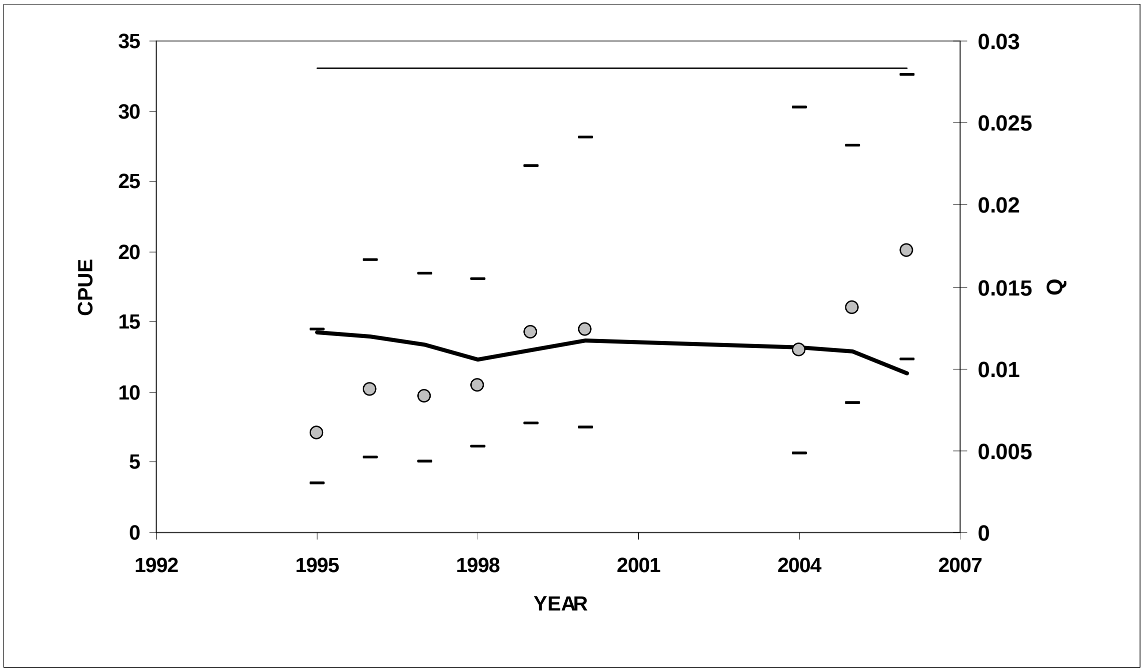

Figure 6.1. Sub-Area 1 Stock Synthesis model estimated standardized CPUE time series (S15) US Hawaii Longline Shallow-Set. Circles are observed CPUE, bold line is model estimate, dashes are +-2*(observed se), and thin line is effective q.

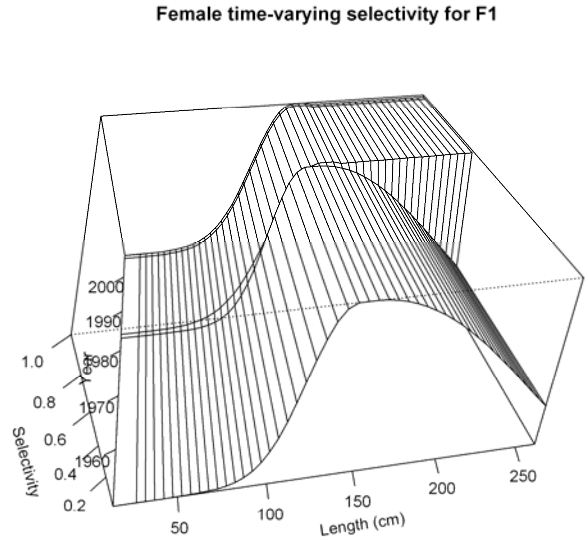

Figure 7.1. Sub-Area 1 length selectivity (F1) Japan Offshore + Distant Water Longline in Region 1-1 (R1-1) (Female = Male; 1951 – 1983, 1984 – 2006).

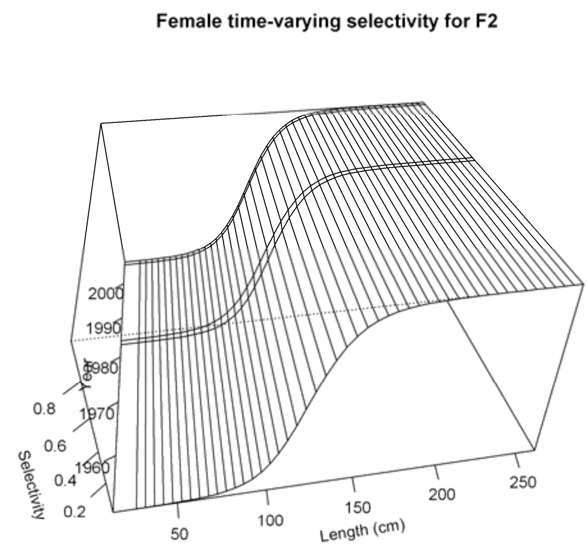

Figure 7.2. Sub-Area 1 length selectivity (F2) Japan Offshore + Distant Water Longline in Region 1-2 (R1-2) (Female = Male; 1951 – 1983, 1984 – 2006).

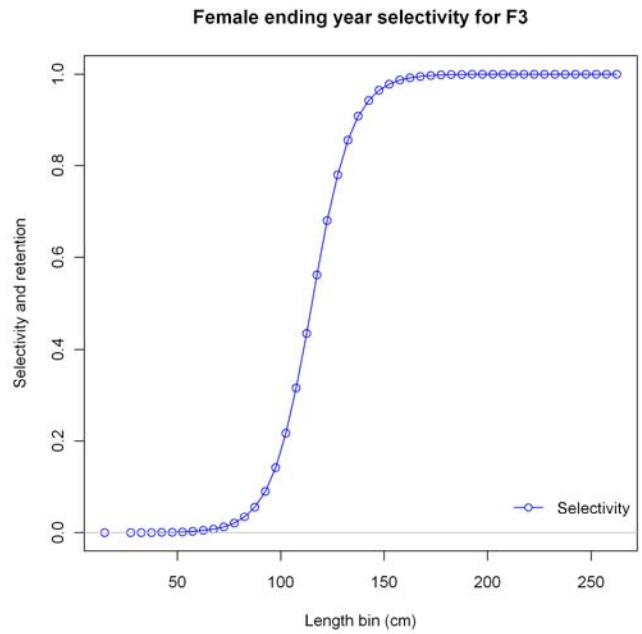

Figure 7.3. Sub-Area 1 length selectivity (F3) Japan Offshore + Distant Water Longline in Region 1-3 (R1-3) (Female = Male; 1951 – 2006).

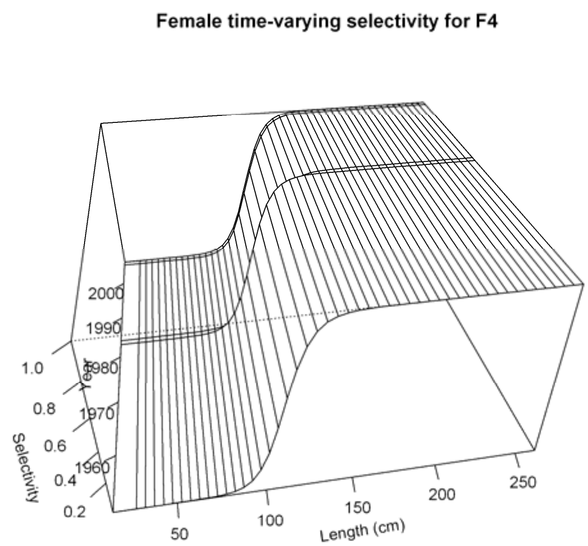

Figure 7.4. Sub-Area 1 length selectivity (F4) Japan Offshore + Distant Water Longline in Region 1-4 (R1-4) (Female = Male; 1951 – 1983, 1984 – 2006).

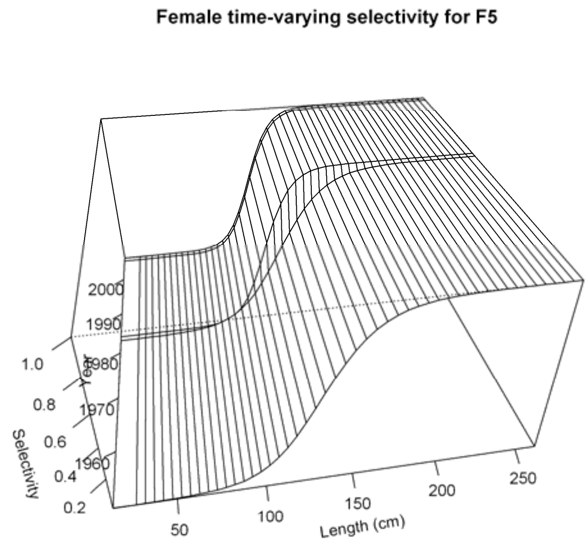

Figure 7.5. Sub-Area 1 length selectivity (F5) Japan Offshore + Distant Water Longline in Region 1-5 (R1-5) (Female = Male; 1951 – 1983, 1984 – 2006).

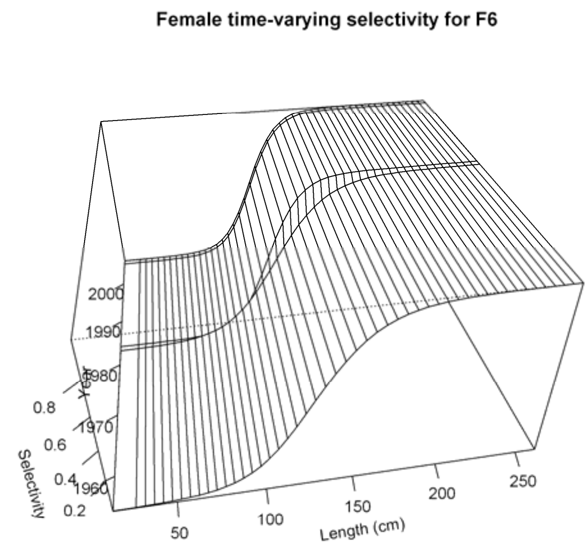

Figure 7.6. Sub-Area 2 length selectivity (F6) Japan Offshore + Distant Water Longline in Region 2-1 (R2-1) (Female = Male; 1955 – 1983, 1984 – 2006).

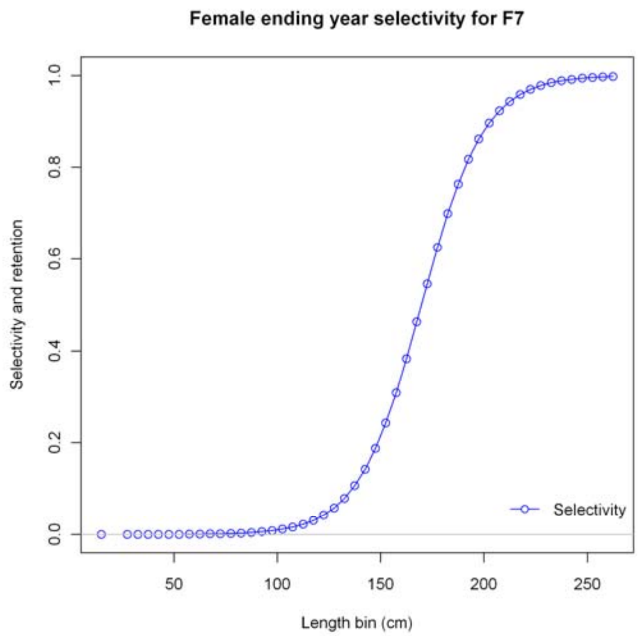

Figure 8. Sub-Area 1 length selectivity (F7) Japan Driftnet in Region 1-1 (R1-1) (Females = Males; 2004 – 2006).

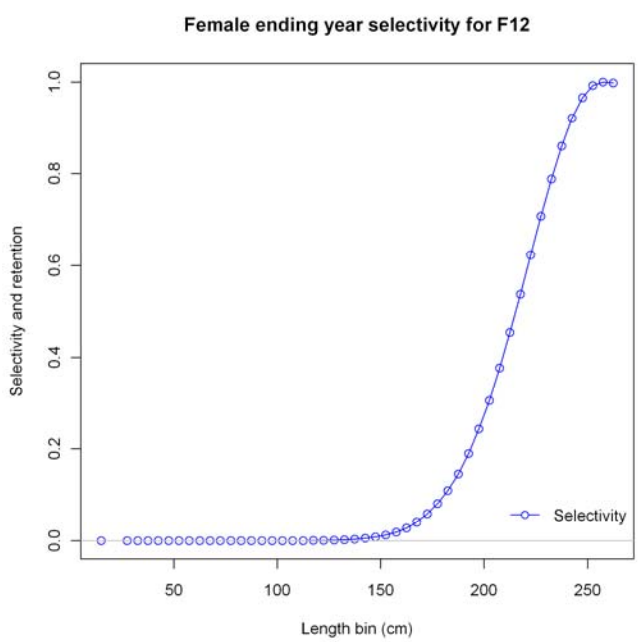

Figure 9. Sub-Area 1 length selectivity (F12) Japan Other Primarily Harpoon in Region 1-1 (R1-1) (Females=Males; 2006 + 2007).

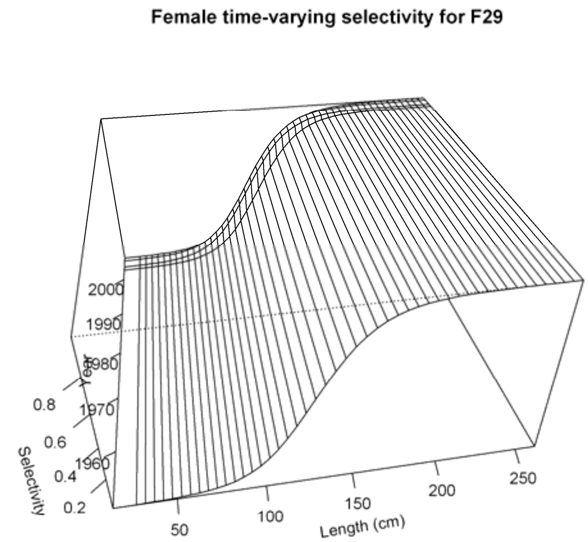

Figure 10. Sub-Area 1 length selectivity (F29) US Hawaii Longline Shallow Set (Females=Males; 1995 – 2003, 2004 – 2006).

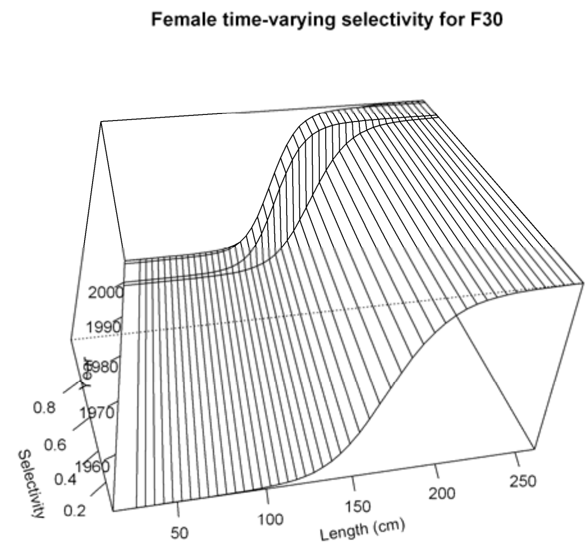

Figure 11. Sub-Area 1 length selectivity (F30) US California Gillnet (Females=Males; 1980 – 1999, 2000 – 2006).

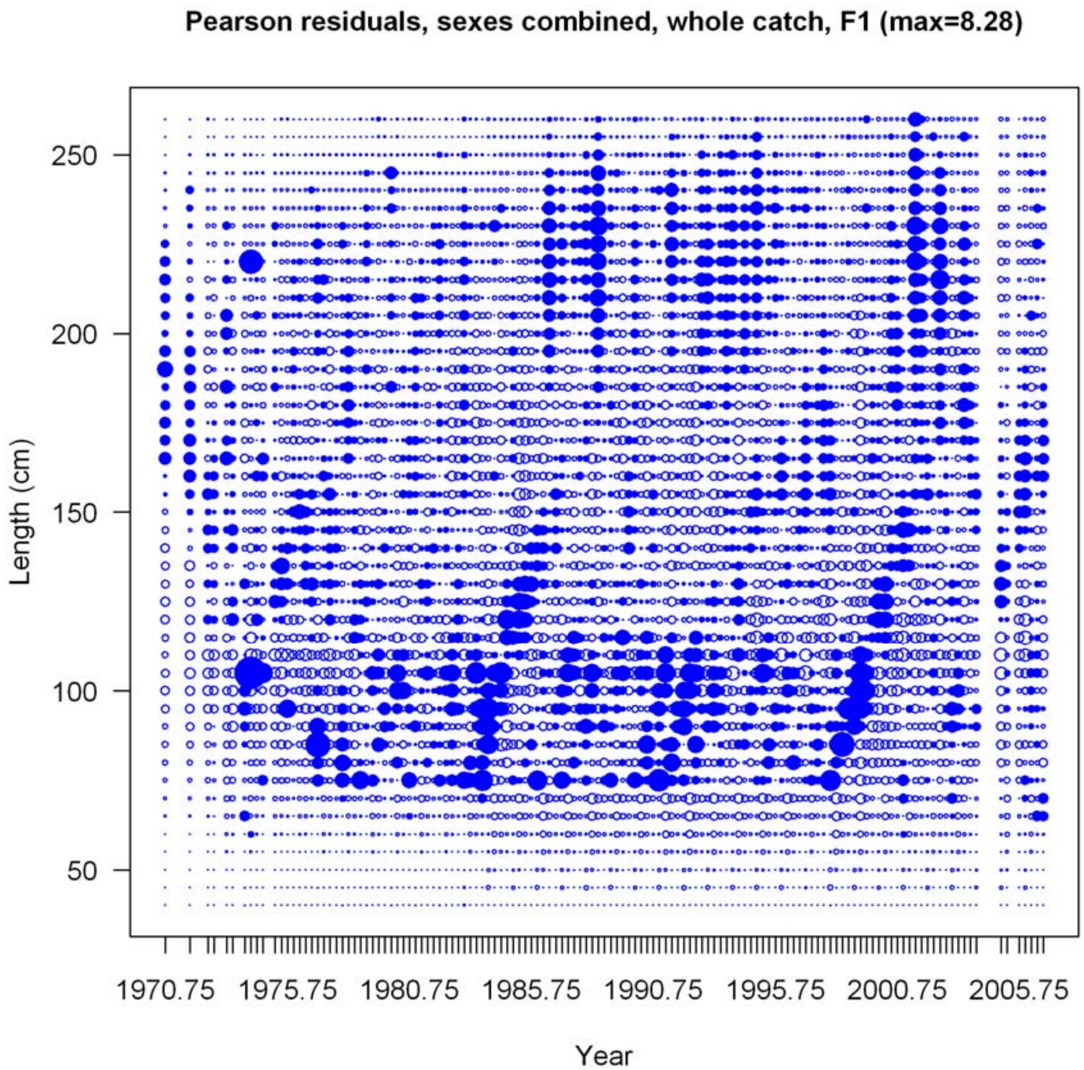

Figure 12.1 Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F1) in Region 1-1 (R1-1). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

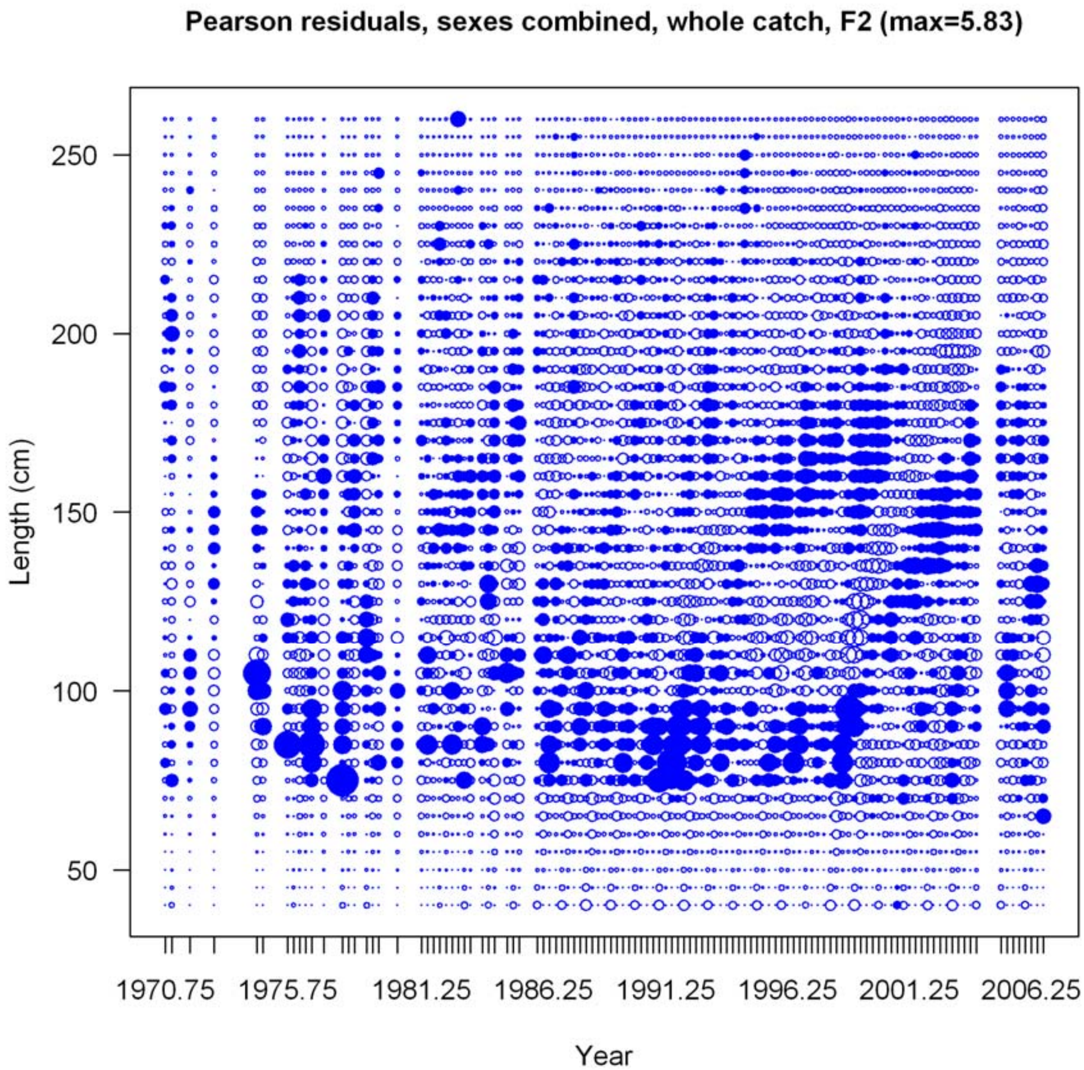

Figure 12.2. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F2) in Region 1-2 (R1-2). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

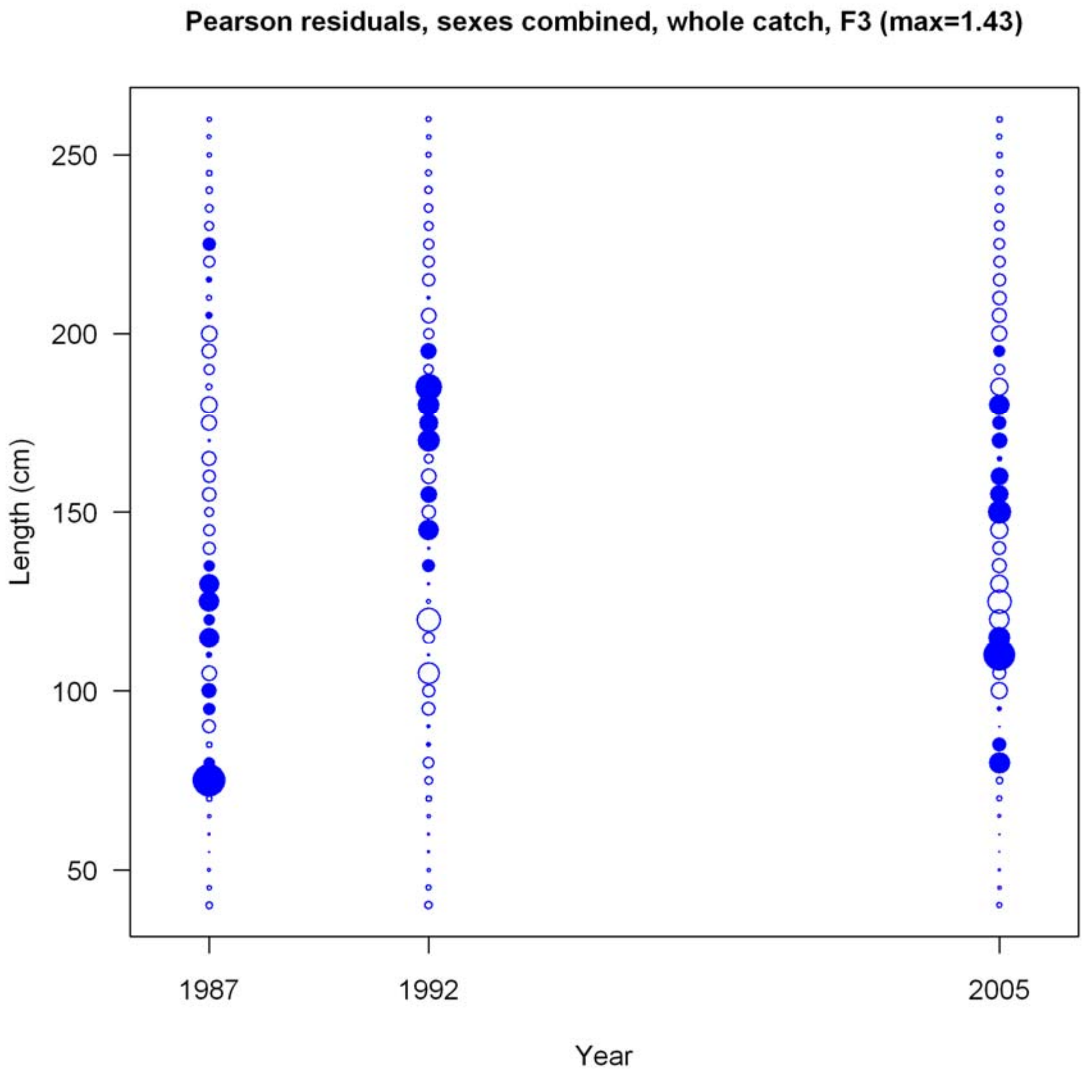

Figure 12.3. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F3) in Region 1-3 (R1-3). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

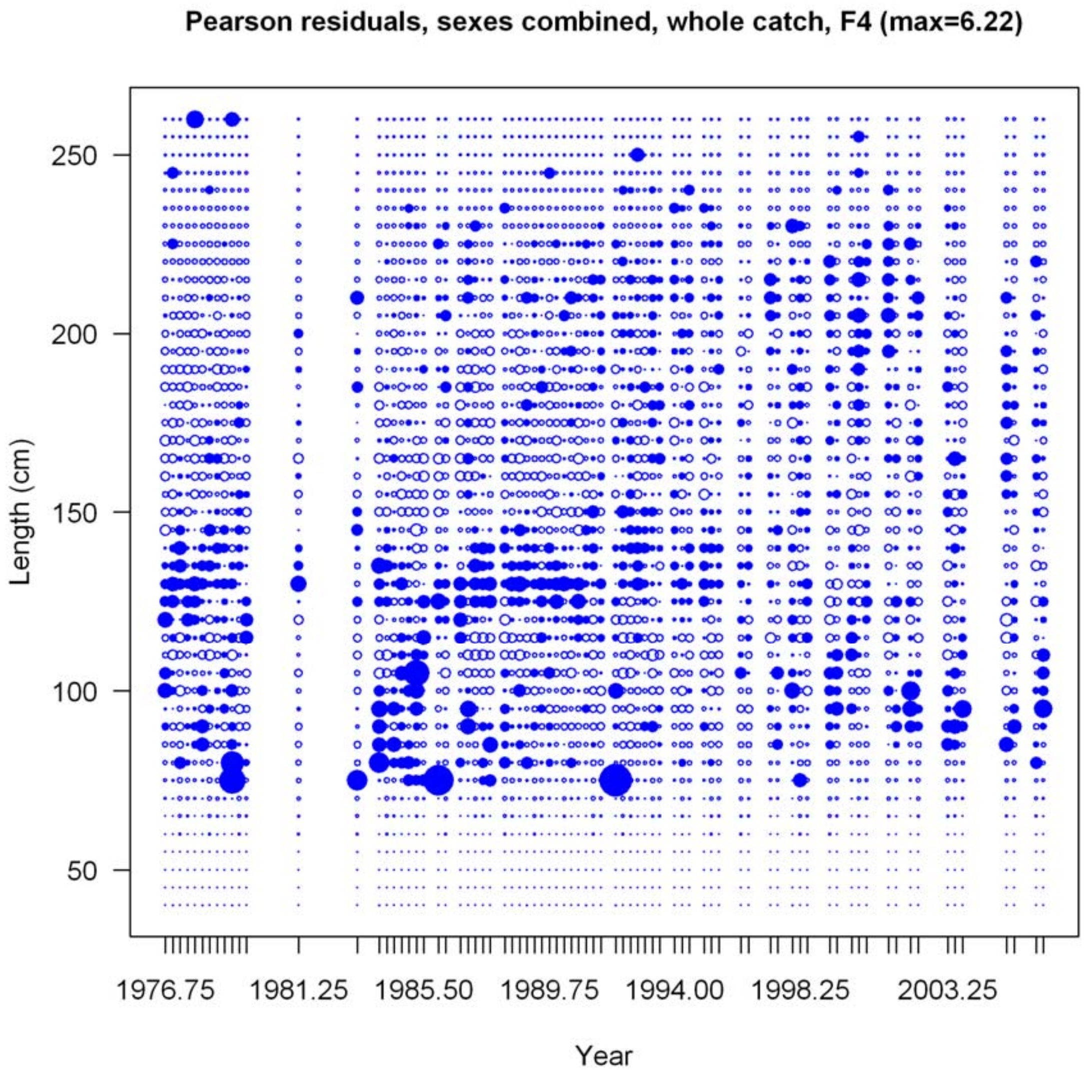

Figure 12.4. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F4) in Region 1-4 (R1-4). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

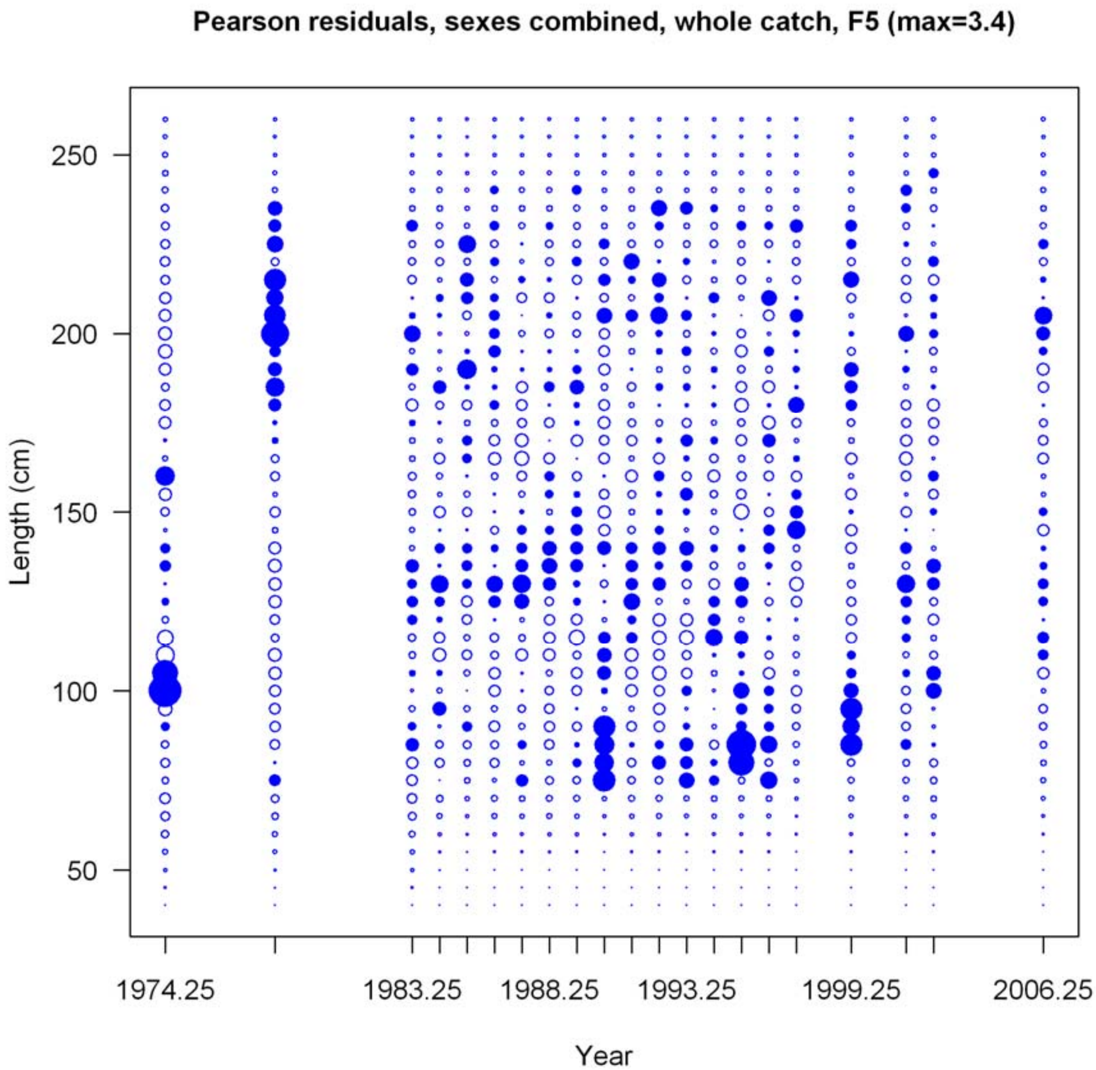

Figure 12.5. Sub-Area 1 length frequency fit for Japan Offshore + Distant Water Longline (F5) in Region 1-5 (R1-5). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

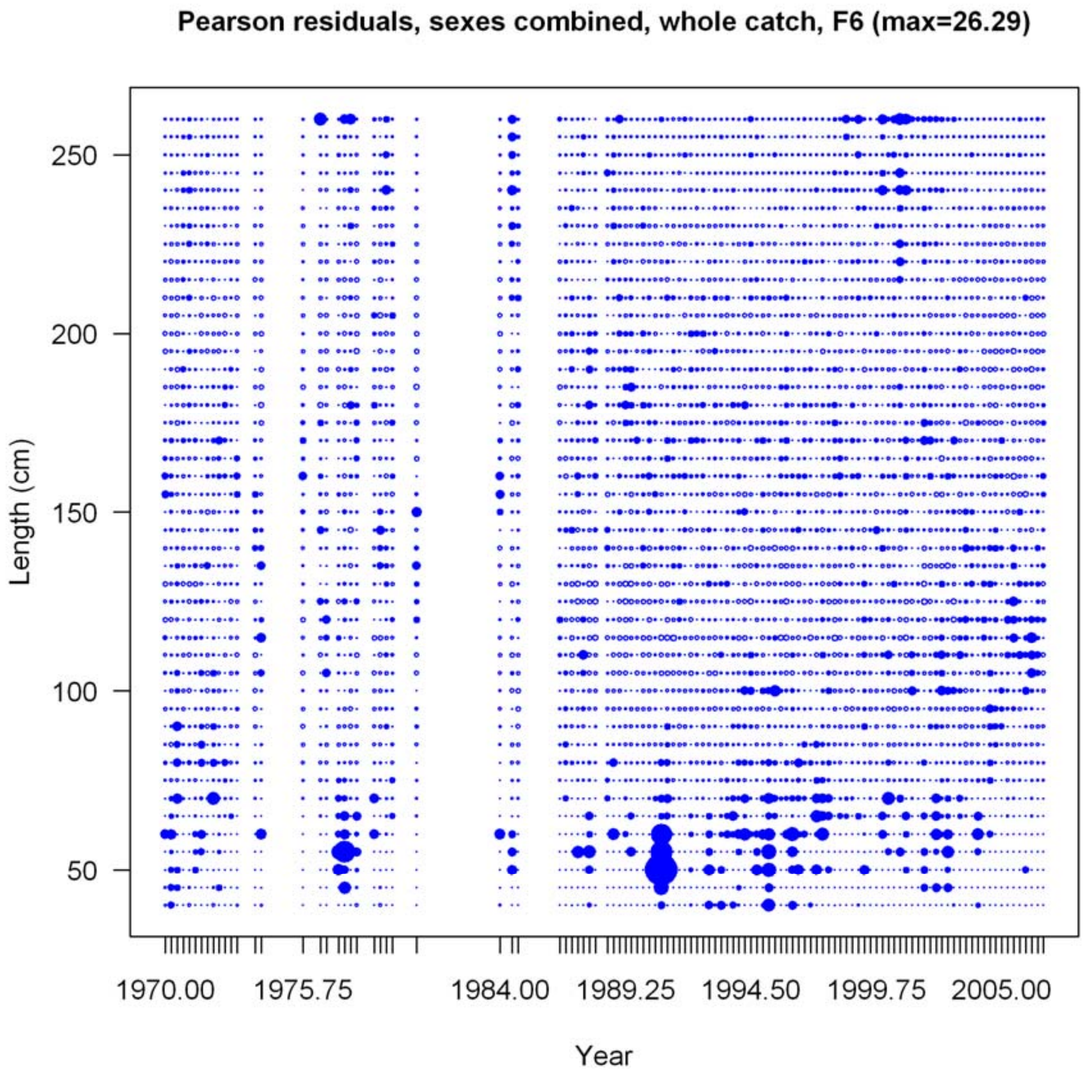

Figure 12.6. Sub-Area 2 length frequency fit for Japan Offshore + Distant Water Longline (F6) in Region 2-1 (R2-1). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

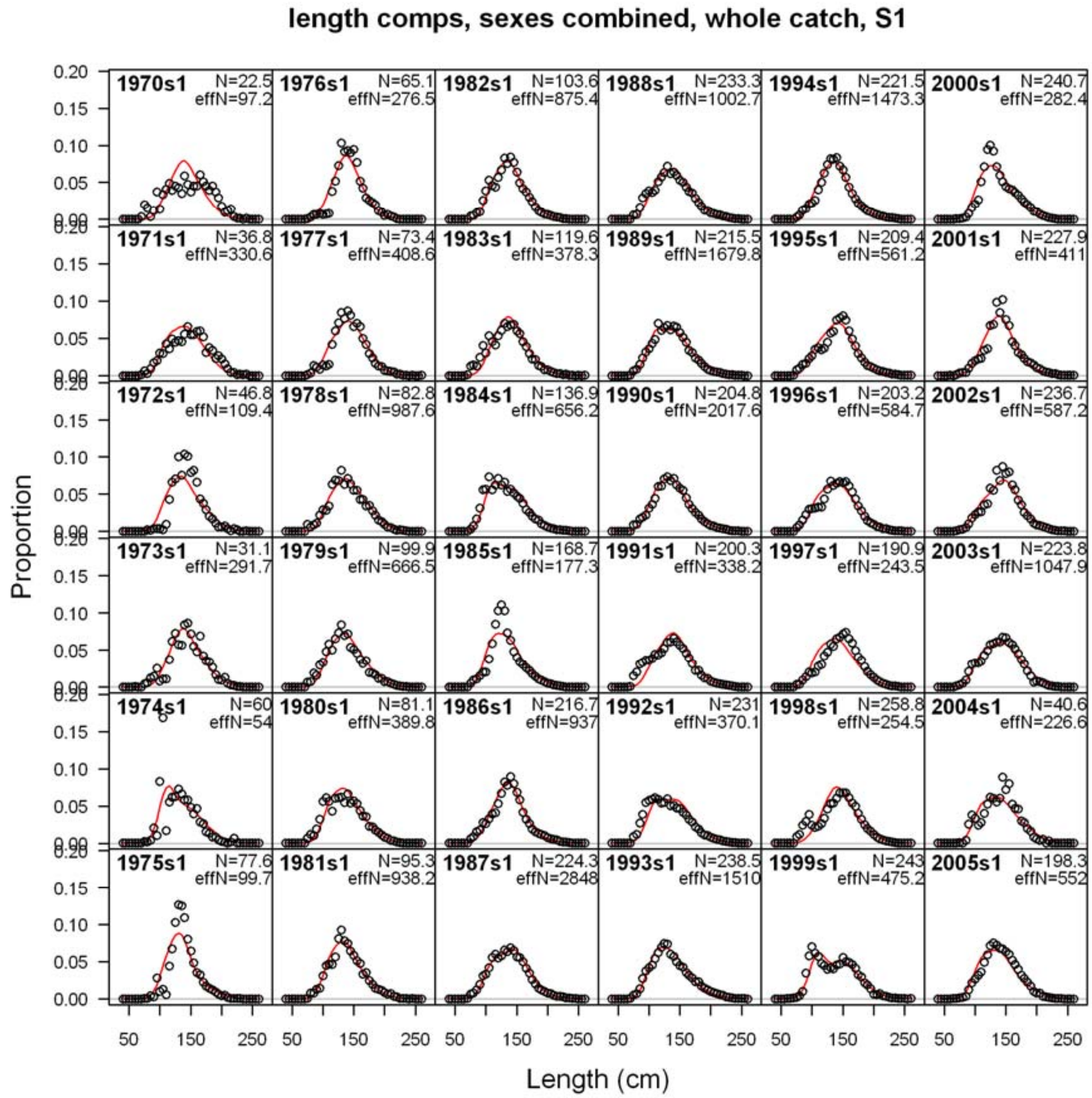

Figure 12.7.1. Sub-Area 1 annual length frequency (S1) Japan Offshore + Distant Water Longline (All regions and quarters combined). Open circles represent observed.

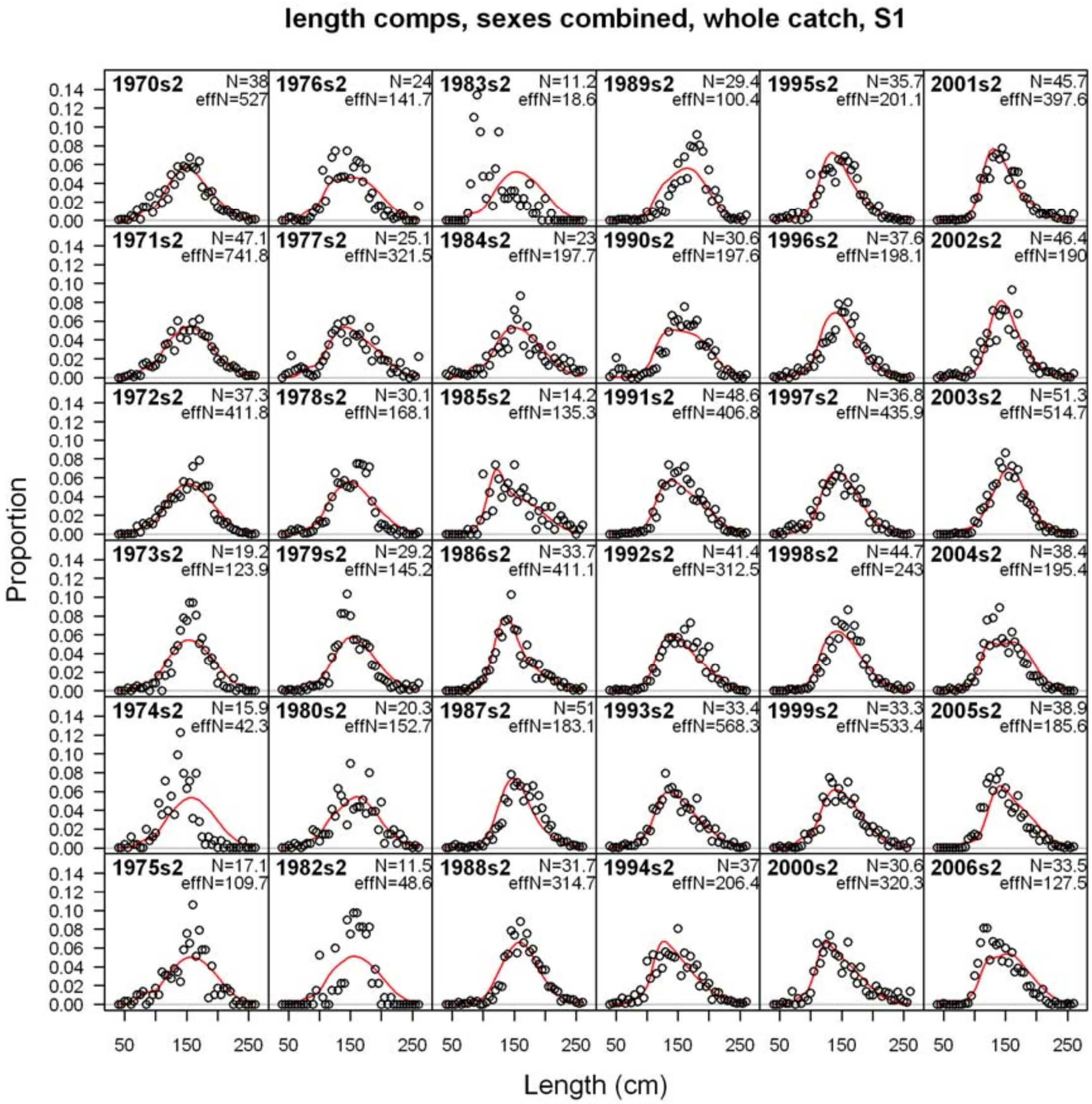

Figure 12.7.2. Sub-Area 2 annual length frequency Japan Offshore + Distant Water Longline (All quarters combined). Open circles represent observed.

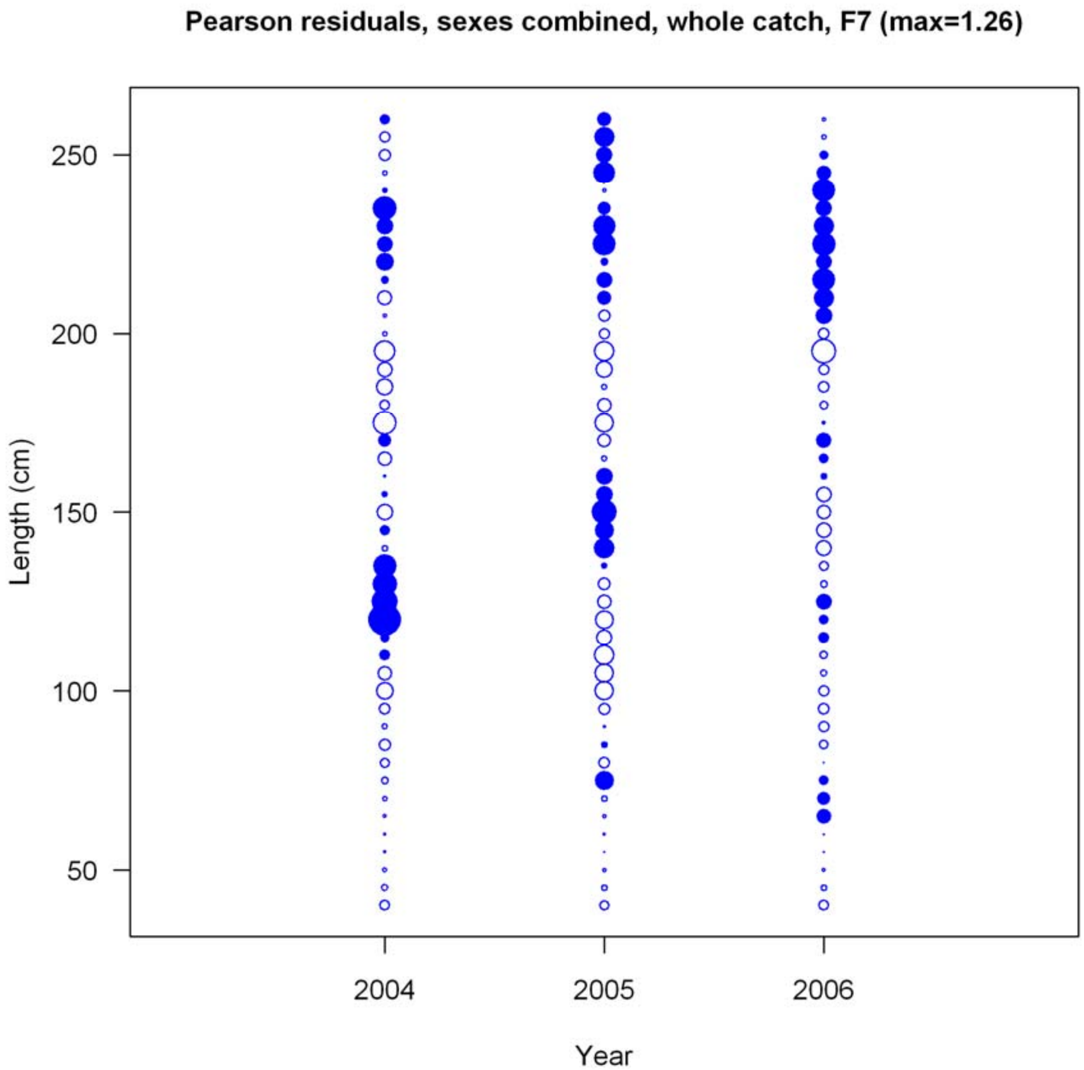

Figure 13. Sub-Area 1 length frequency fit for Japan Driftnet (F7) in Region 1-1 (R1-1). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

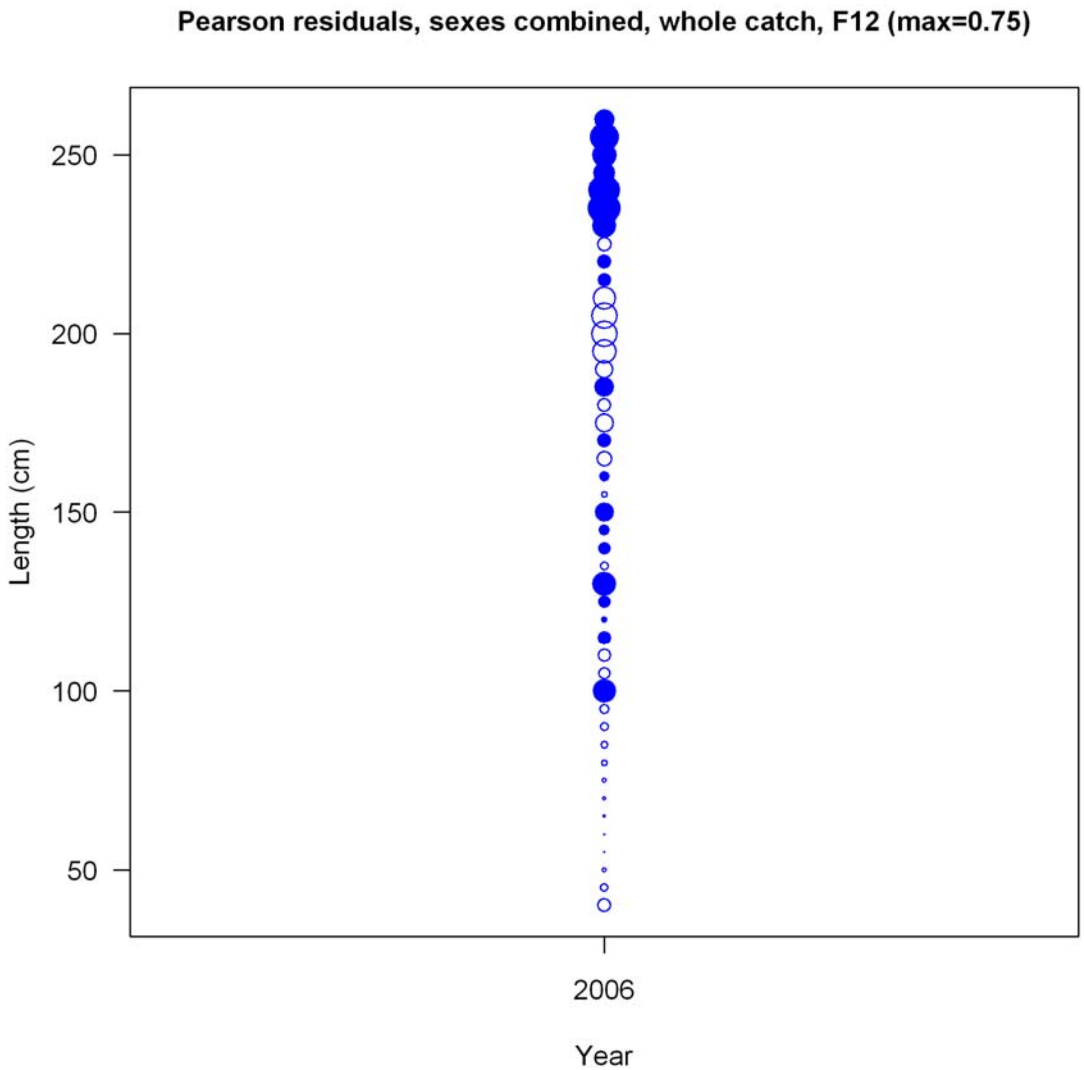

Figure 14. Sub-Area 1 length frequency fit for Japan Other Primarily Harpoon (F12) in Region 1-1 (R1-1). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

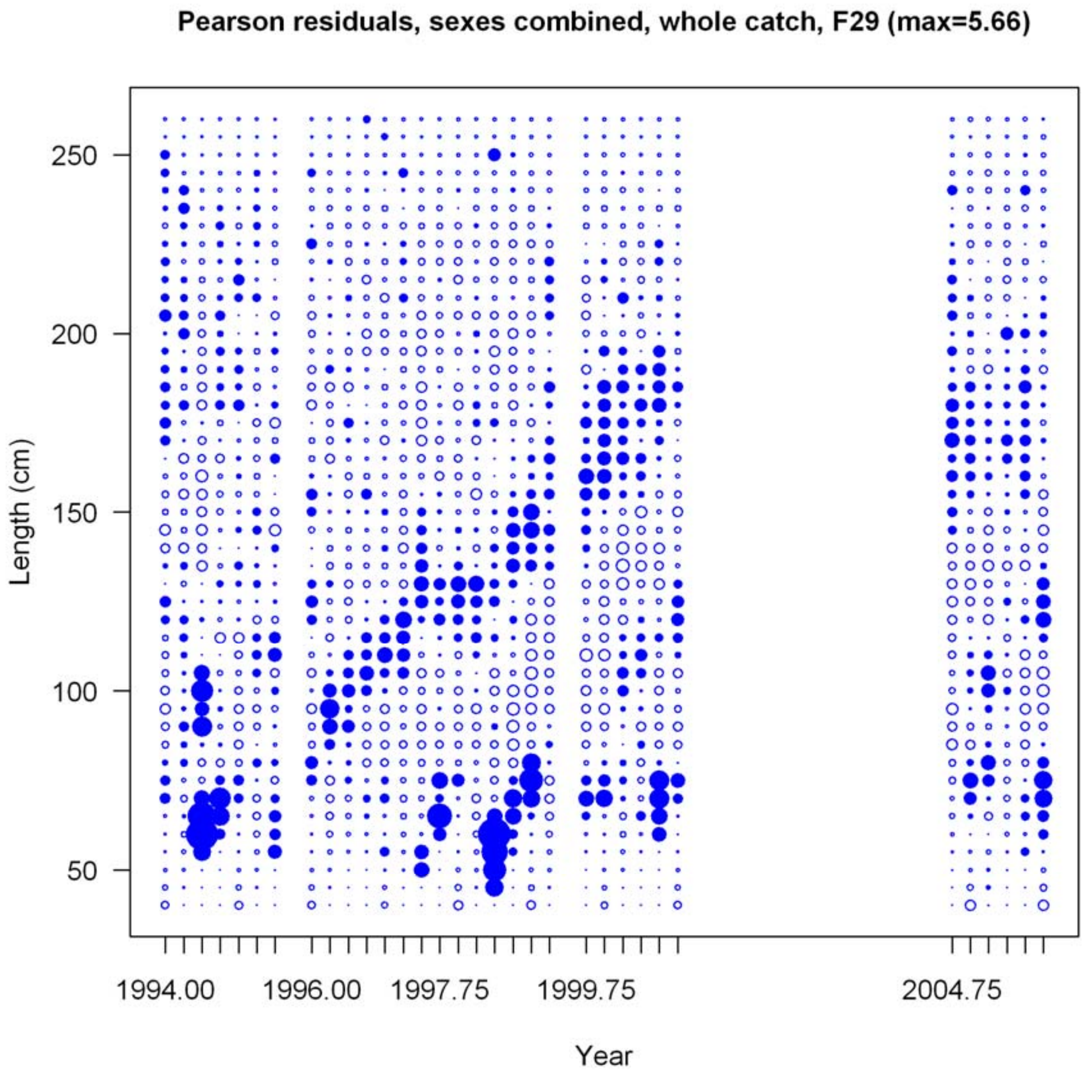

Figure 15. Sub-Area 1 length frequency fit for US Hawaii Longline Shallow Set (F29). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

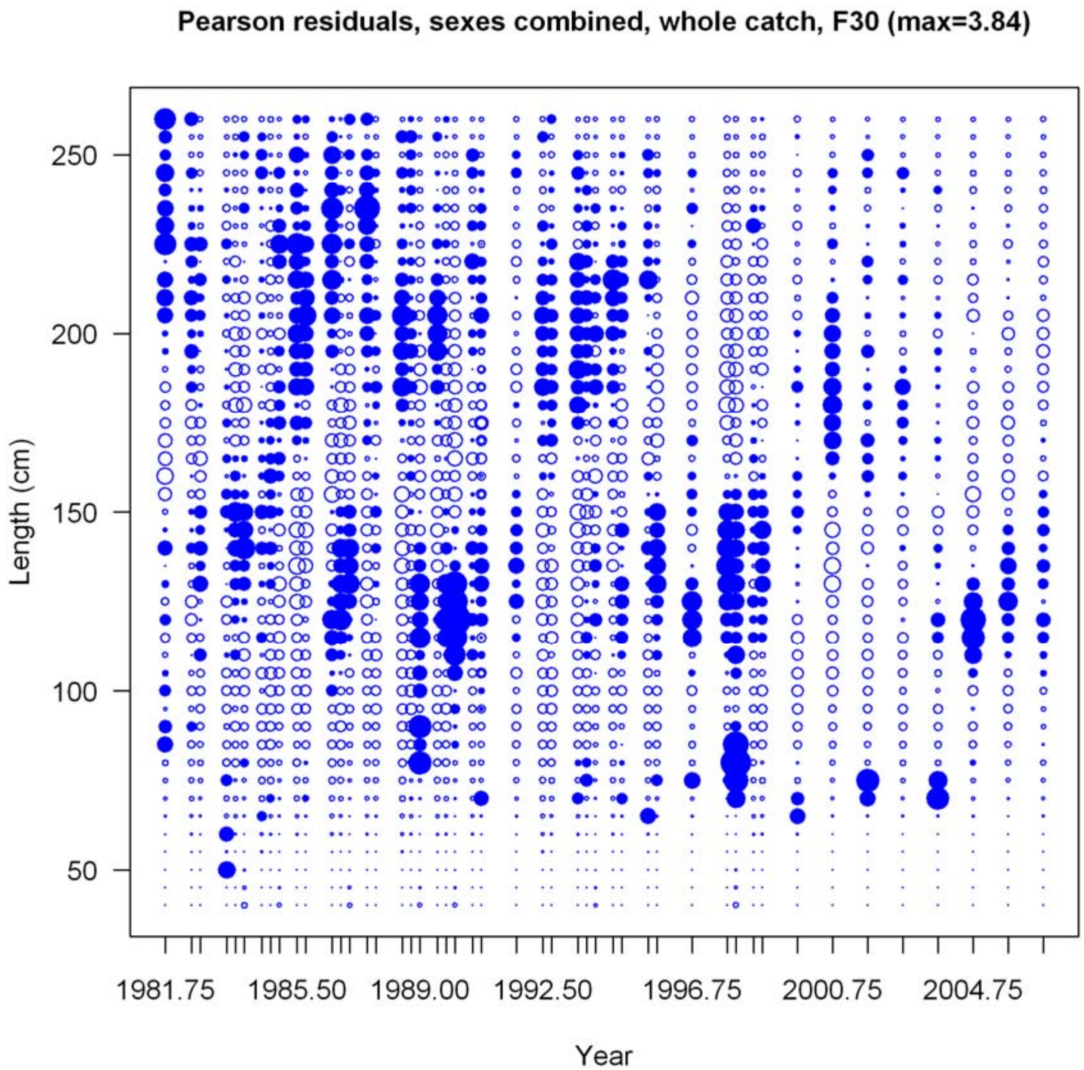

Figure 16. Sub-Area 1 length frequency fit for US California Gillnet (F30). Circle width represents the Pearson residuals (observed-predicted)/sqrt(var(predicted)). Closed circles represent fewer predicted than observed.

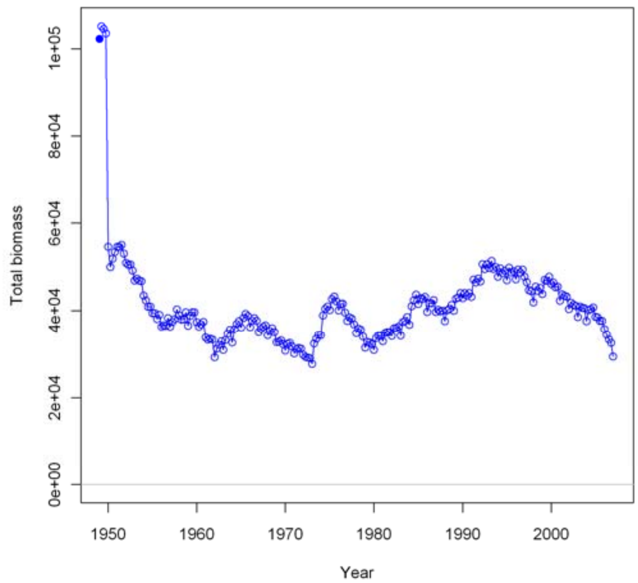

Figure 17.1. Sub-Area 1 Stock Synthesis model estimated total biomass (mt).

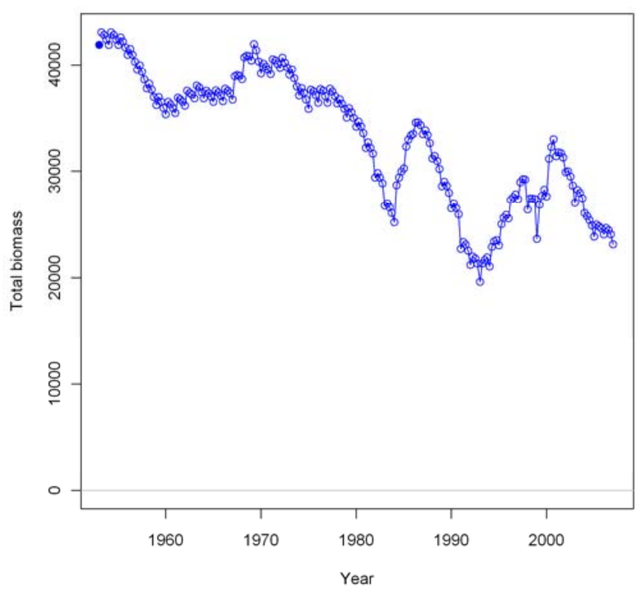

Figure 17.2. Sub-Area 2 Stock Synthesis model estimated total biomass (mt).

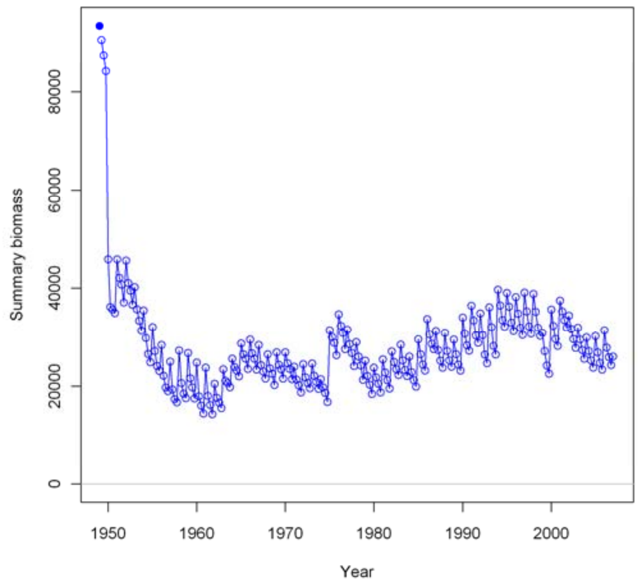

Figure 18.1. Sub-Area 1 Stock Synthesis model estimated summary biomass (Age 2+ mt).

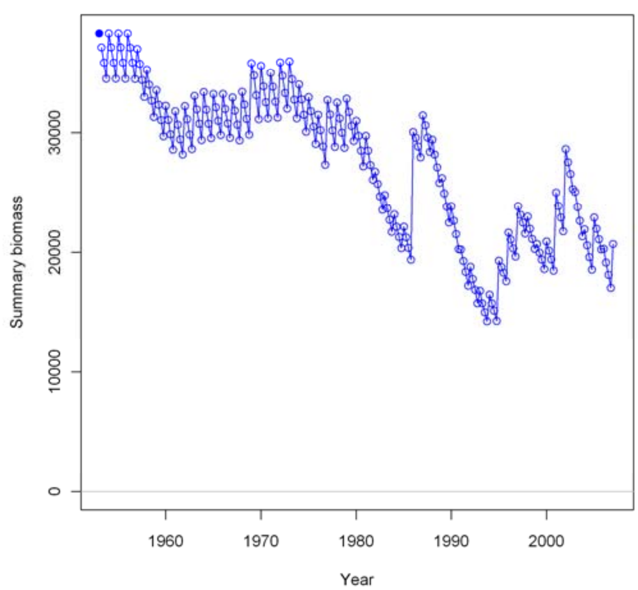

Figure 18.2. Sub-Area 2 Stock Synthesis model estimated summary biomass (Age 2+ mt).

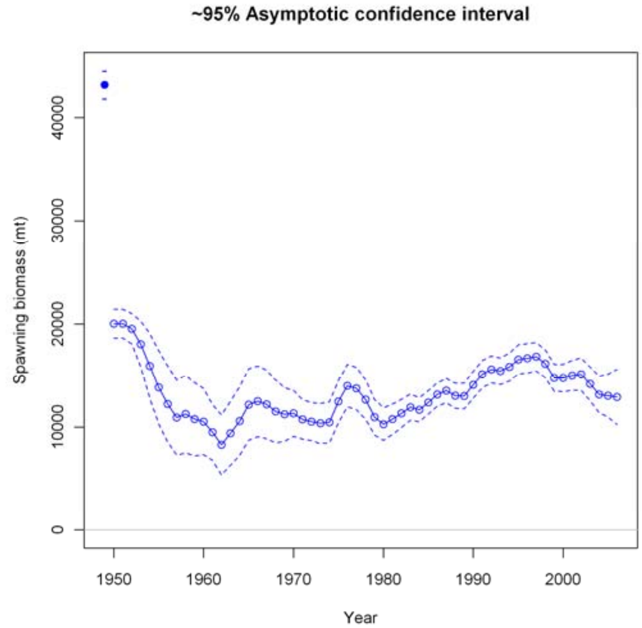

Figure 19.1. Sub-Area 1 model estimated mature female spawning biomass (mt) and 95% confidence interval calculated as +-2 * (model estimated se of annual spawning biomass).

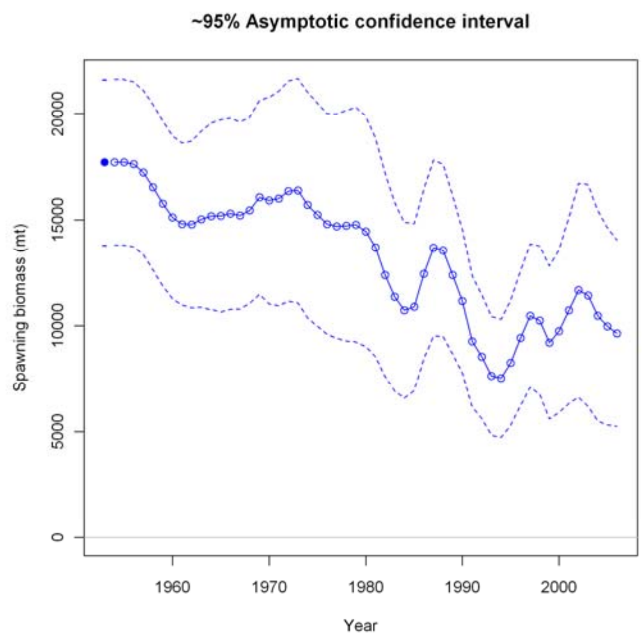

Figure 19.2 Sub-Area 2 model estimated mature female spawning biomass (mt) and 95% confidence interval calculated as +-2 * (model estimated se of annual spawning biomass).

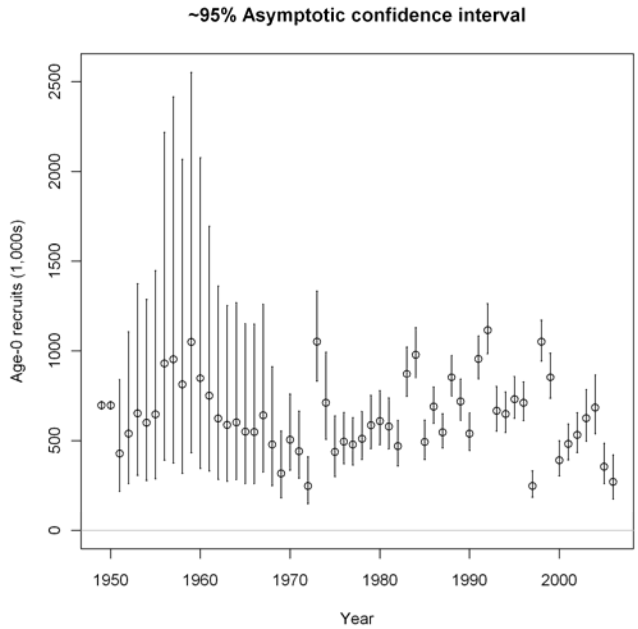

Figure 20.1. Sub-Area 1 model estimated age-0 recruitment (1,000s).

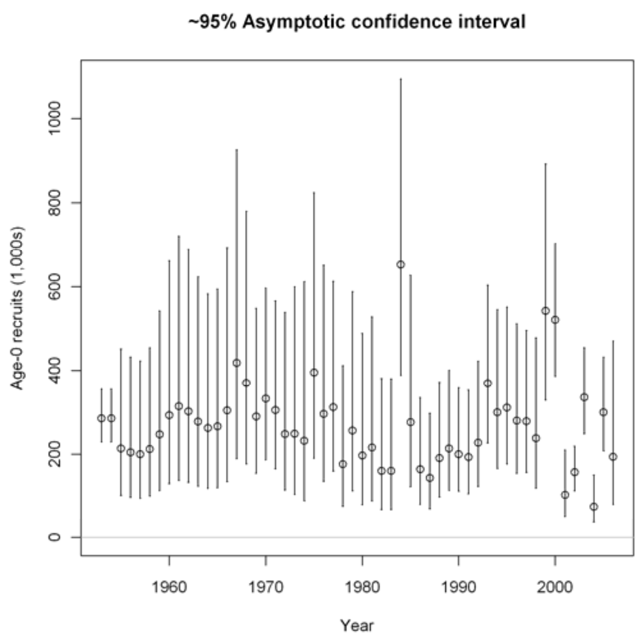

Figure 20.2. Sub-Area 2 model estimated age-0 recruitment (1,000s).

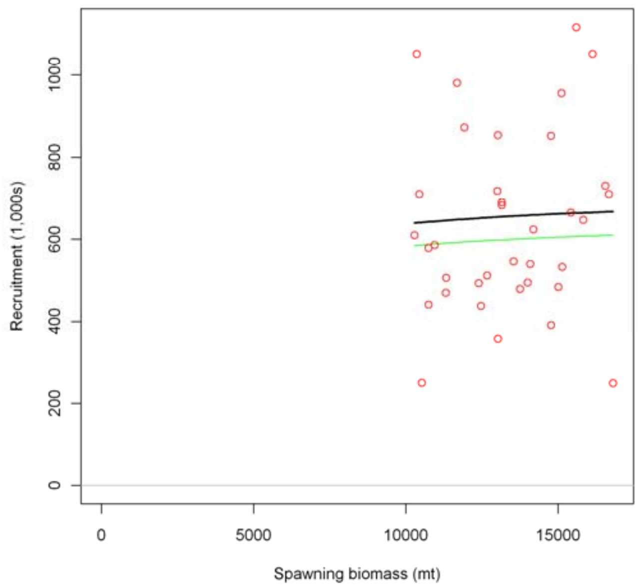

Figure 21.1. Sub-Area 1 model estimated Beverton-Holt spawner-recruit relationship for a fixed steepness (h = 0.9). Bold line is not biased adjusted.

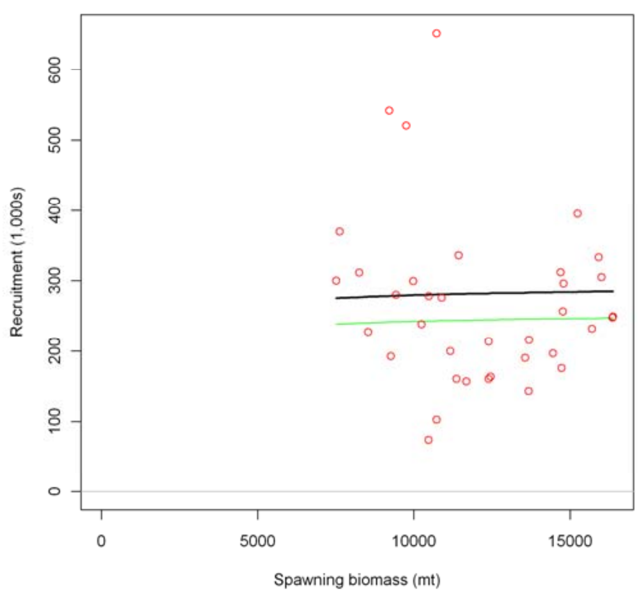

Figure 21.2. Sub-Area 2 model estimated Beverton-Holt spawner-recruit relationship for a fixed steepness (h = 0.9). Bold line is not biased adjusted.

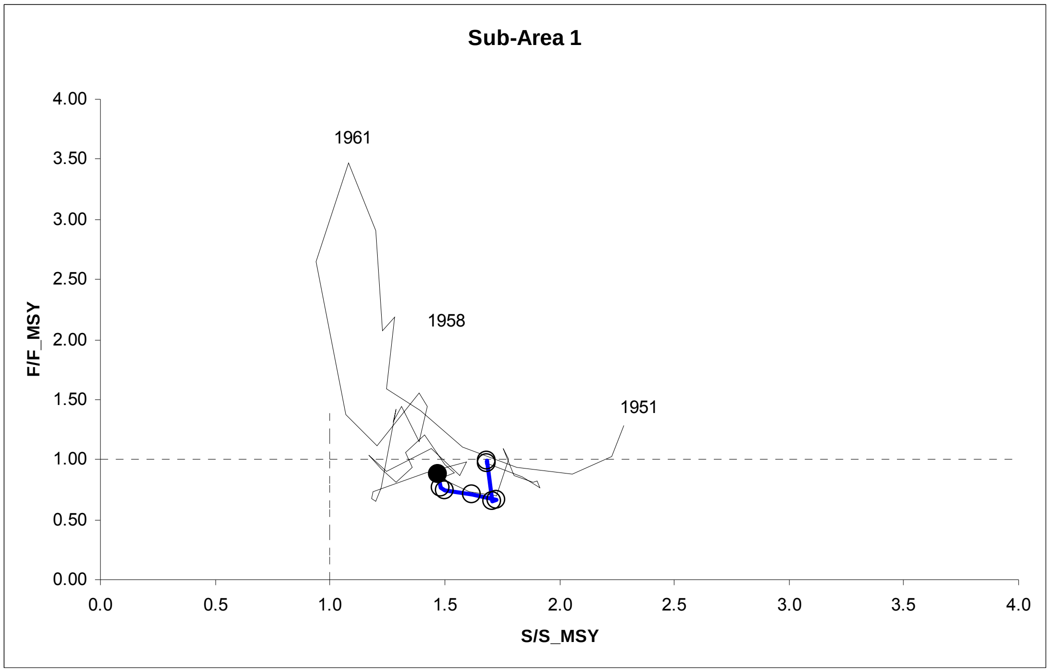

Figure 22.1 Sub-Area 1 Stock Synthesis model "Kobe" plots of female spawning biomass (S) relative to female spawning biomass at MSY (S_MSY) and fishing mortality (F) relative to fishing mortality at MSY (F_MSY). Bold line represents the years 1999 – 2006; Solid circle represents year 2006.

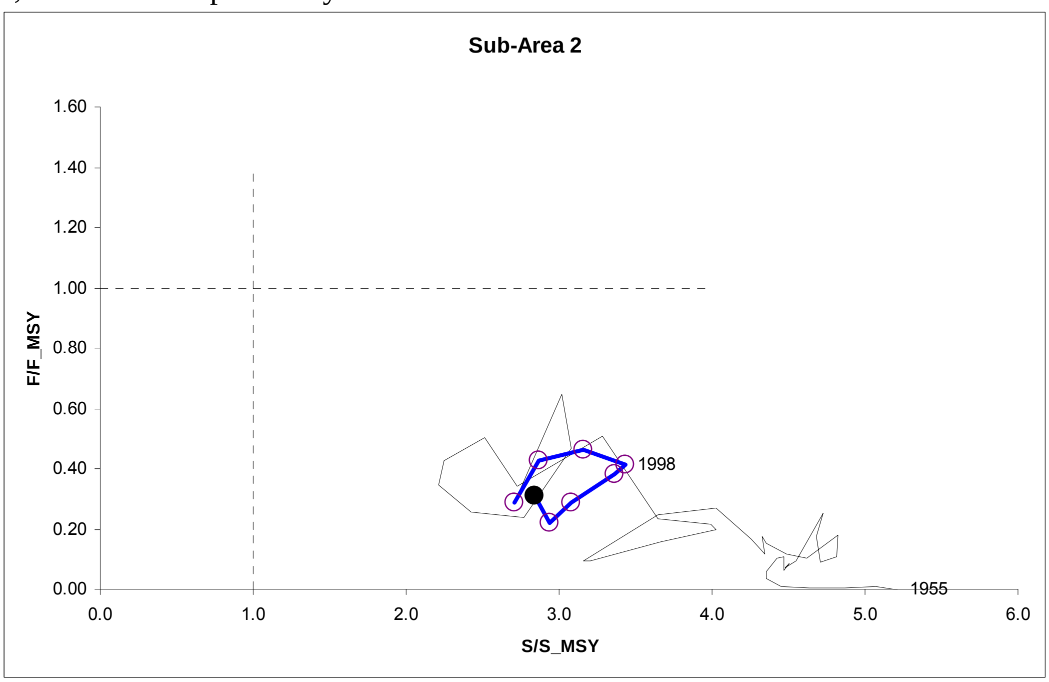

Figure 22.2 Sub-Area 2 Stock Synthesis model "Kobe" plots of female spawning biomass (S) relative to female spawning biomass at MSY (S_MSY) and fishing mortality (F) relative to fishing mortality at MSY (F_MSY). Bold line represents the years 1999 – 2006; Solid circle represents year 2006.

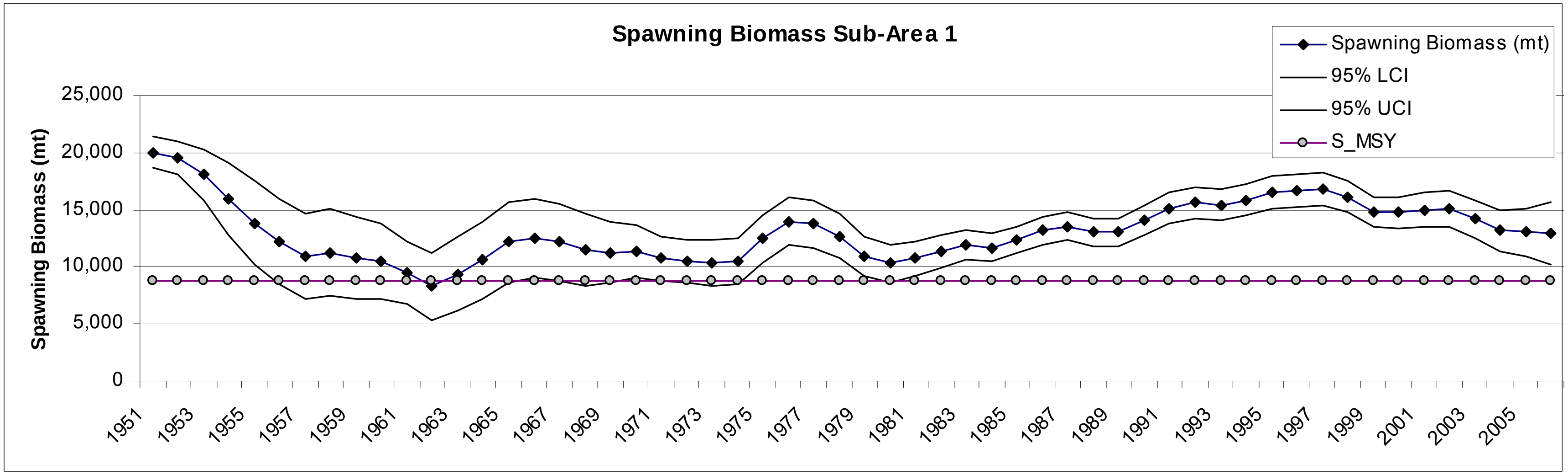

Figure 23.1. Sub-Area 1 Stock Synthesis model estimated female spawning biomass (S) along with female spawning biomass at MSY (S_MSY).

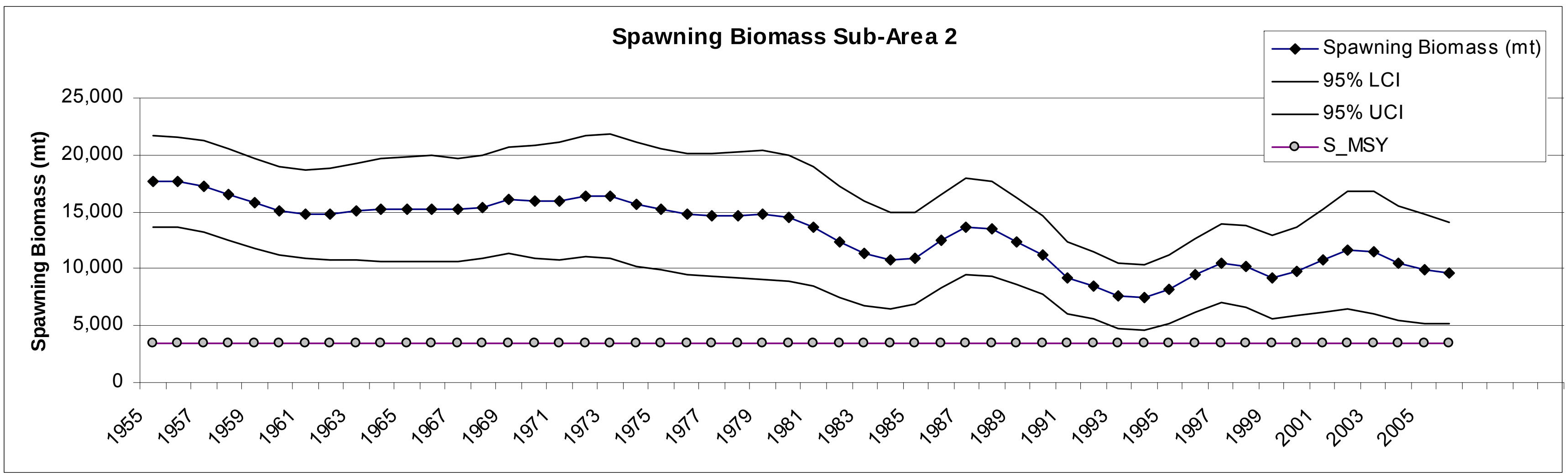

Figure 23.2. Sub-Area 2 Stock Synthesis model estimated female spawning biomass (S) along with female spawning biomass at MSY (S_MSY).

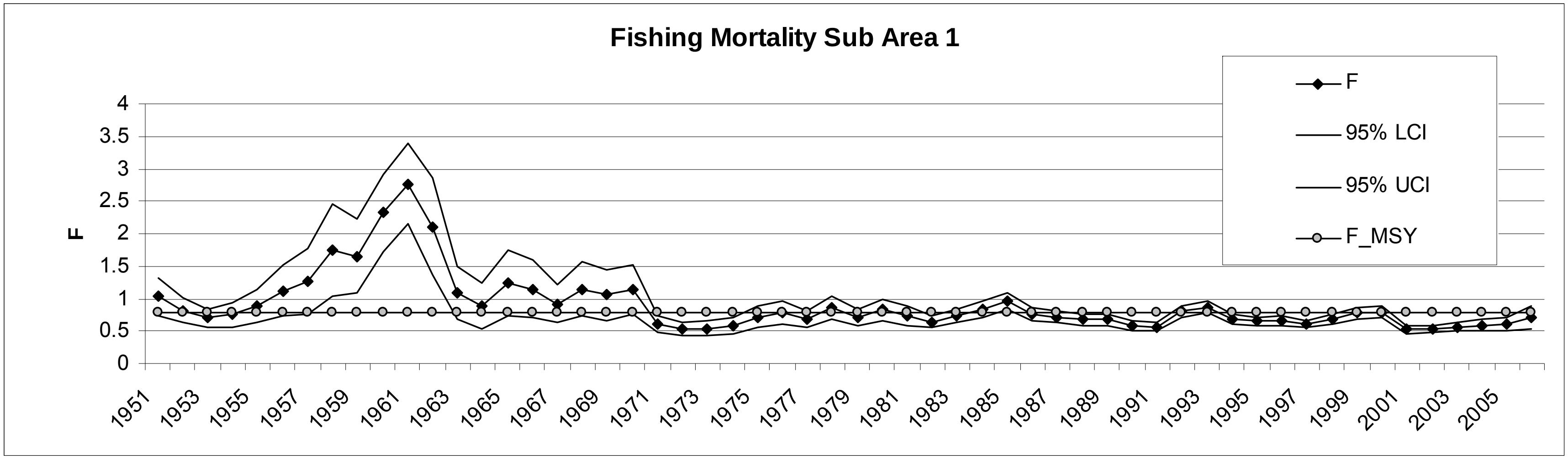

Figure 24.1. Sub-Area 1 Stock Synthesis model estimated fishing mortality (F) along with fishing mortality at MSY (F_MSY).

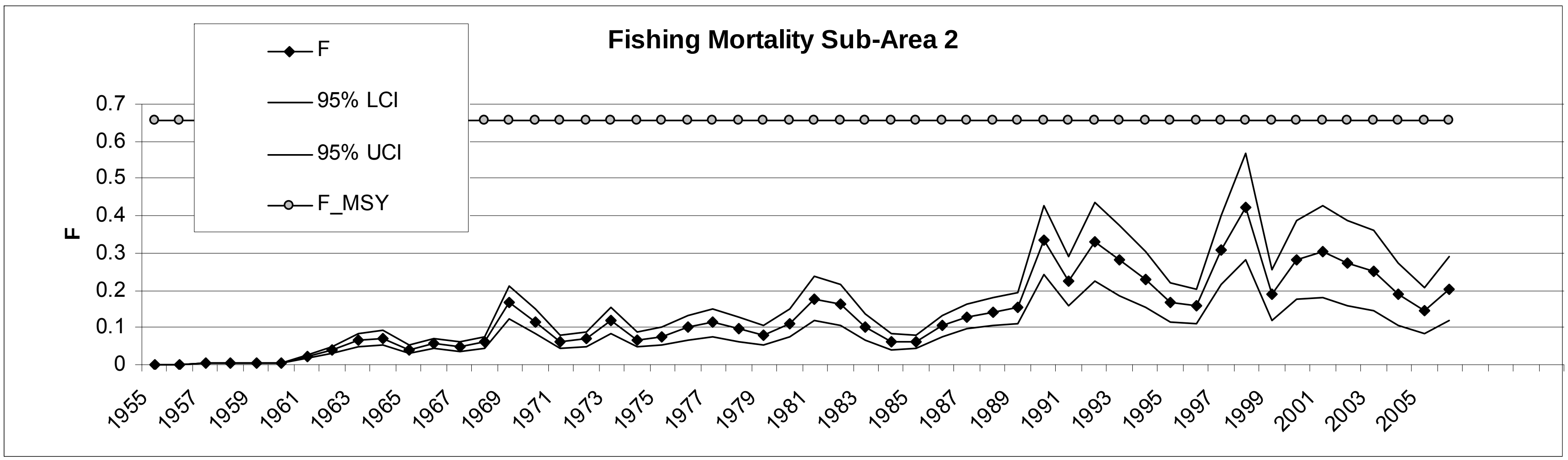

Figure 24.2. Sub-Area 2 Stock Synthesis model estimated fishing mortality (F) along with fishing mortality at MSY (F_MSY).

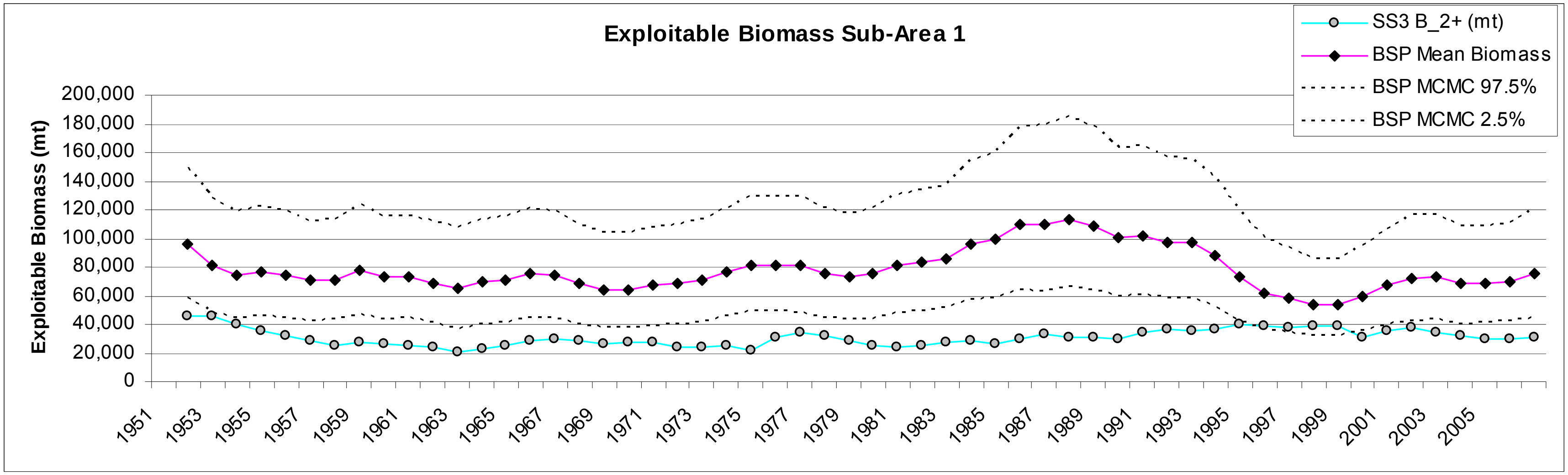

Figure 25.1. Sub-Area 1 Stock Synthesis model estimated time-series of age 2+ biomass (B_2+) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass (BSP Mean Biomass) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak and Ishimura 2009, BILL-WG 2009b).

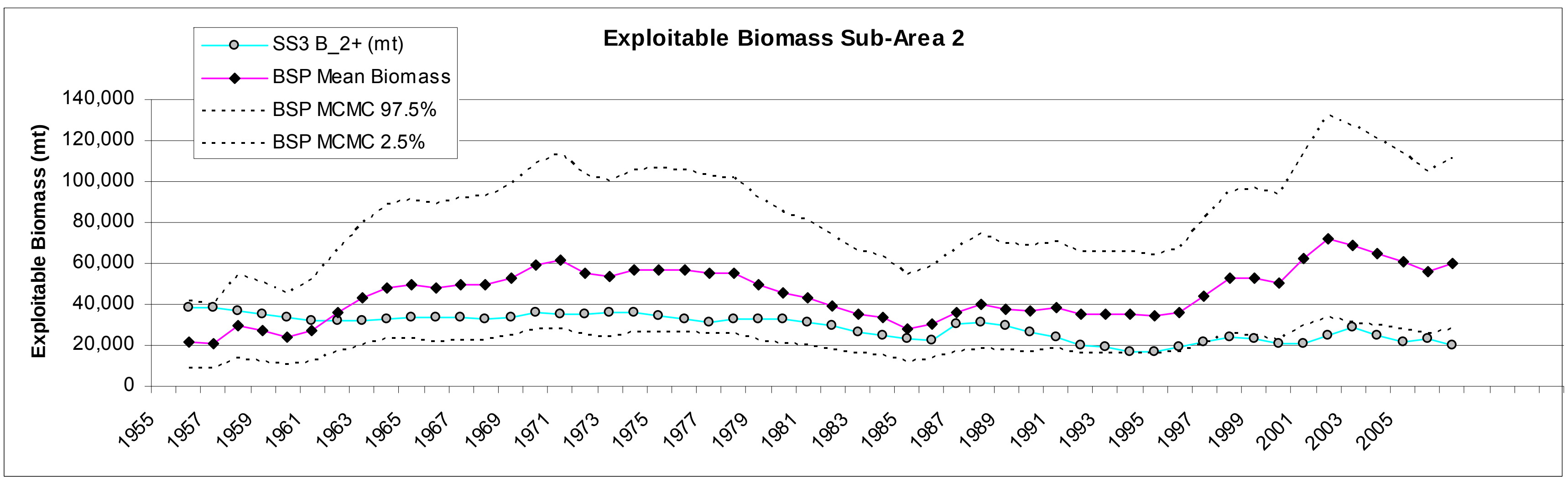

Figure 25.2. Sub-Area 2 Stock Synthesis model estimated time-series of age 2+ biomass (B_2+) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass (BSP Mean Biomass) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak and Ishimura 2009, BILL-WG 2009b)

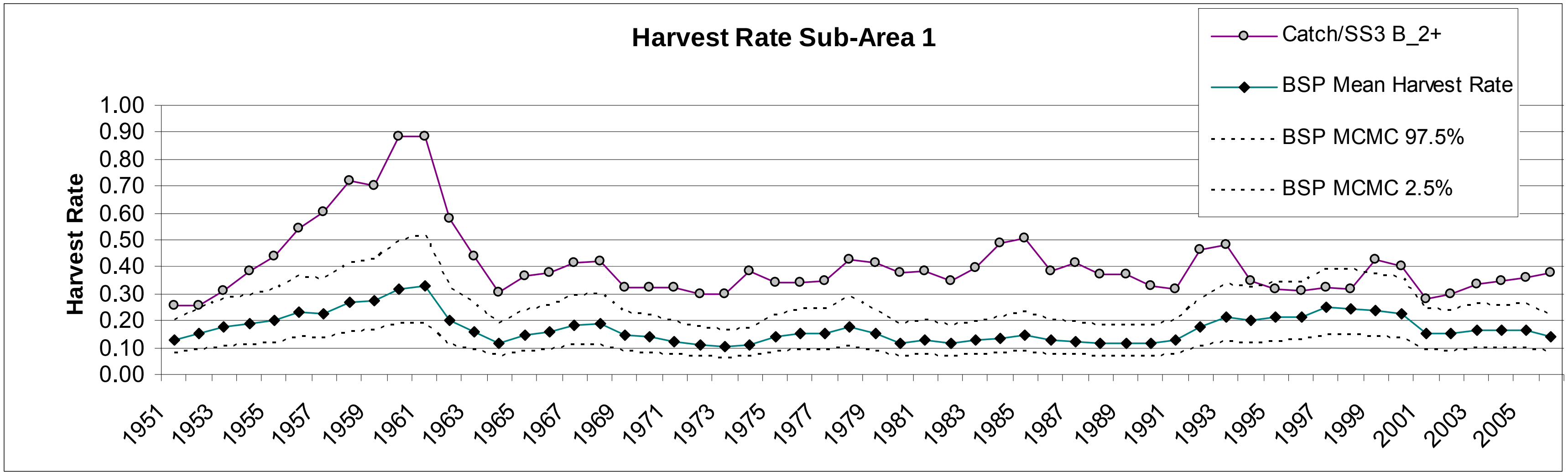

Figure 26.1. Sub-Area 1 Stock Synthesis model estimated time series of total exploitation (Catch mt)/(B_2+ mt) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass harvest rates (BSP Mean Harvest Rate) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak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

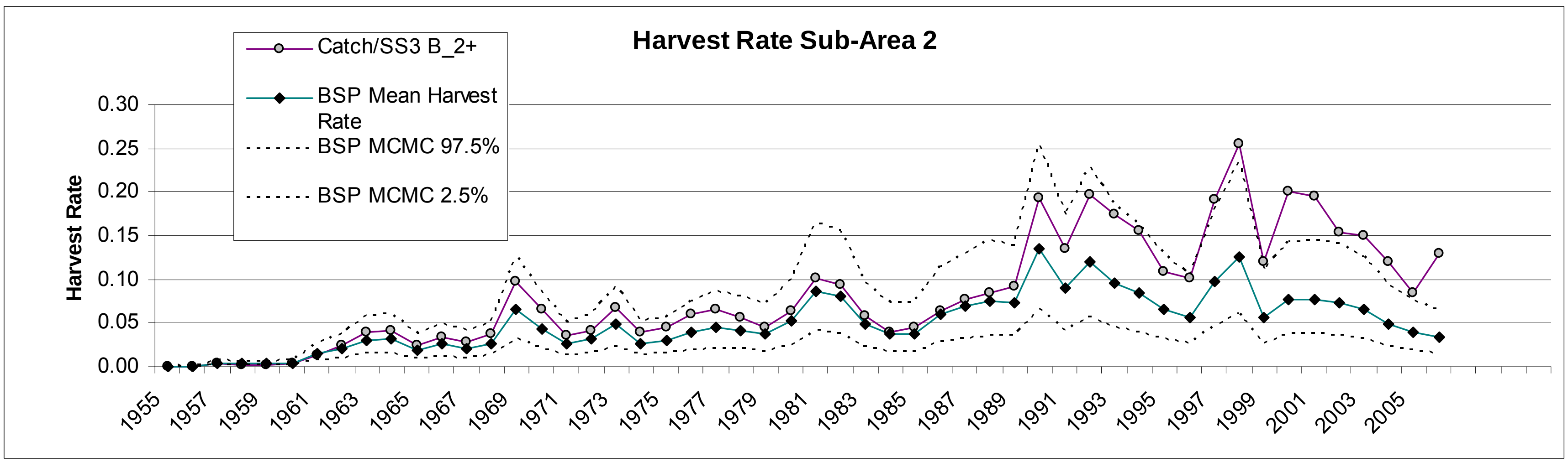

Figure 26.2. Sub-Area 2 Stock Synthesis model estimated time series of total exploitation (Catch mt)/(B_2+ mt) along with Bayesian surplus production (BSP) estimates of mean exploitable biomass harvest rates (BSP Mean Harvest Rate) and 95% confidence intervals (BSP MCMC 2.5%, 97.5%) reproduced from (Brodziak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