ISC/07/MAR&SWOWG-1/02

International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

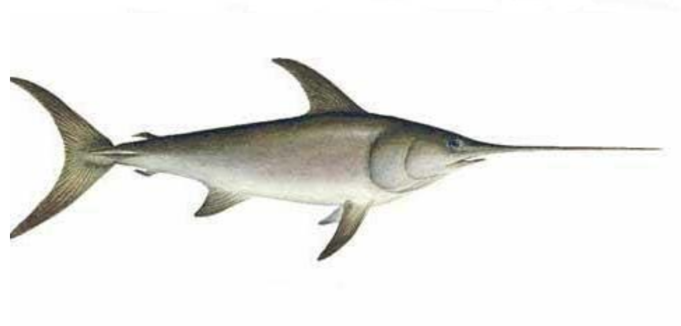
SS2 Sensitivity Runs for Striped Marlin Assessment WG 2007[1]

Kevin Piner
NOAA NMFS Southwest Fisheries Science Center
La Jolla, California, USA

Raymond Conser
NOAA NMFS Southwest Fisheries Science Center
La Jolla, California, USA

Gerard DiNardo
NOAA NMFS Pacific Islands Fisheries Science Center
Honolulu, Hawaii, USA

Jon Brodziak
NOAA NMFS Pacific Islands Fisheries Science Center
Honolulu, Hawaii, USA



[1]Working document submitted to the ISC Billfish Working Group Workshop, 19-27 March 2007, Chinese Taipei. Document not to be cited without author's written permission.

Draft report do not cite

SS2 Sensitivity Runs for Striped Marlin Assessment WG 2007.

Kevin Piner and Ray Conser
Southwest Fisheries Science Center
NOAA Fisheries
8604 La Jolla Shores Drive
La Jolla, Ca 92037

Gerard DiNardo and Jon Brodziak
Pacific Islands Fisheries Science Center
NOAA Fisheries
2570 Dole Street
Honolulu, HI 96822

Introduction

Striped Marlin (*Tetrapturus audax*) is a wide-ranging member of the billfish family *Istiophoridae*. They are among the most widely distributed of the billfishes, with abundance reportedly increasing with distance from the continental shelf (Kailola et al. 1993). Considerable uncertainty remains about the data, basic biology, distribution, stock structure and movement patterns of this species. Despite the gaps in our knowledge of striped marlin, the Striped Marlin Working Group (SMWG) of the International Scientific Committee (ISC) recommended assessing the stock status in the North Pacific Ocean (NPO) using data compiled at a WG meeting in Shimizu, Japan November, 2007. Given the uncertainty in stock structure, a single NPO wide stock was assumed.

At the November, 2007 SMWG meeting in Shimizu, Japan, the WG recommended that a stock assessment be conducted Using Stock Synthesis II. Preliminary examination of the sensitivity of the model to key assumptions should be examined prior to the meeting in Taipei in 2007. A more detailed description of the parameterization of the model and the sensitivity analysis conducted is given in the methods section.

Stock Synthesis II (SS2 v 1.23e) is a stock assessment model that estimates the population dynamics of a stock through use of a variety of fishery dependent and fishery independent information. Stock Synthesis has been the primary assessment tool for groundfishes off the Pacific West coast of the United States for nearly a decade. In 2004, SS2 was recoded using AD Model Builder to take advantage of the advanced features and processing speed of that modeling platform. The structure of the model allows for Bayesian estimation, use of the Markov-Chain Monte Carlo (MCMC) algorithm as well as parametric bootstrapping methods and the normal approximation using the inverse of the negative Hessian to characterize parameter uncertainty.

SS2 incorporates 3 primary model subcomponents, **1)** a population subcomponent that recreates estimates of the numbers/ biomass at age of the population using estimates of M, growth, fecundity, catch etc., **2)** an observational sub-component that consists of the observed (measured) quantities such as CPUE or proportion at length/age, and **3)** a statistical sub-component that quantifies using likelihoods the fit of the observations to the recreated population. For a complete description see "Technical Description of the Stock Synthesis II Assessment Program Version 1.23" by Richard Methot.

Because of the generalized nature of the SS2 code, models can be configured to perform over a range of complexity, from a biomass dynamic model (Piner et al. 2005) to a spatially and temporally structured model (Methot and Stewart 2005). These kinds of integrated analyses are common in assessments of groundfish (Piner et al. 2005, Piner et al. 2000) off the Pacific coast of the U.S. The complexity of the model is defined by the types and complexity of the underlying population and the available data types. A nice feature of this kind of structural flexibility is that various levels of complexity can be run using the same operational files, allowing the easy comparison of different assumptions. We note here that to implement spatial dynamics (movement) the newest version of SS2 (v 2.0) needs to be used. As of March 1, 2007 the v. 2.0 is still a beta version thus was not used for this meeting but should be used in subsequent assessments.

This paper presents the results of WG prescribed sensitivity runs for use in determining the appropriate configuration to characterize stock status. Results presented in this document do not constitute an official description of the stock status but should be interpreted as sensitivity runs to evaluate model performance to aid in developing the stock assessment at the 2007 WG meeting. Details of the data considered, likelihood components and model structure are given in the methods section.

Methods

Data

Data were originally compiled by the SMWG at a November, 2005 meeting in Honolulu, Hawaii and at the November, 2006 meeting in Shimizu Japan. Subsequent to this meeting new information was incorporated and final data sets (summarized) were distributed to stock assessment teams march, 2007. For detailed descriptions of the data see the working papers describing this information. This paper includes no data treatment beyond using the summarized series to model the population dynamics. The following sections give a brief overview of the biology and data used:

Stock Structure

For the purpose of this assessment, striped marlin in the North Pacific Ocean is considered a single stock. Catch and CPUE are compiled by regions that are thought to relatively homogeneous with respect to population dynamics or fishery operations. Area definitions were as follows:

Area 1: 20-40^{o} N Lat, West of 180^{o} Long
Area 2: Equator to 20^{o} N. Lat, West of 180^{o} Long

Area 3: 20-40^o N Lat, 180-125^o W Long
Area 4: Equator to 20^o N. Lat, 180-125^o W Long
Area 5: Equator to 40^o N Lat, East of 125^o W Long

Growth
The age-length relationship was characterized by the Von Bertalanffy growth curve (Melo-Barrera et al. 2003), where K=0.23 and Linf=225cm LJFL. This estimate is smaller than Sillman and Young (1976) estimated in the north central Pacific, or those from more distant waters (Merrett 1971; van der Elst 1981; Holdsworth and Saul 2004). Because the length composition information is collected in EFL, the growth parameters were converted from LJFL to EFL using a relationship described in Ware and Sakagawa (1975). The length-weight relationship was described by $W=0.0000972L^{2.57}$ (Ware and Sakagawa 1975), and maturity-at-length was described by a logistic function where 50% maturity occurs at 155 cm EFL and essentially assumed knife-edge maturity (Figure 1). Natural Mortality was assumed to be M=0.3 yr^{-1}, which corresponds to approximately 1% of a cohort surviving to age 15.

Catch
A total of 29 individual fisheries were identified at the November WG meeting and their catch (in #'s of fish) inputted into the model. Years with missing catch were assumed to be zero catch. The historical period (pre 1964) was characterized by stable catches of 100,000-200,000 fish (Figure 2). Total catch peaked in the early-mid 1960 at around 400,000- 500,000 fish. Catch steadily declined after the peak to similar levels as the history (100,000-200,000) by the end of the series.

Striped marlin catch occurs primarily in only 2 of the 5 areas. Roughly 60% of the striped marlin catch has been taken in area 1. Area 5 accounts for roughly 10-20% of the total catch, and the other 3 areas make up the remaining catch.

CPUE
Nine CPUE series were compiled and distributed by the SMWG for potential use in the model. We defined the 9 series by area and fleet and each series is defined below:

Area 1- Japanese Distant Water longline (JPN DW LL); Japanese Coastal Longline (JPN C LL)
Area 2- Japanese Distant Water longline; Japanese Coastal Longline
Area 3- Japanese Distant Water lonline; Hawaiian longline (HWN LL)
Area 4- Japanese Distant Water lonline; Hawaiian longline
Area 5- Japanese Distant Water longline

The WG combined the above mentioned 9 area-specific series into 3 CPUE series using an area weighted approach within the same fishing fleet type (example all JPN DW LL). A total of 66 CPUE observations (Table 1) were used in the fitting. The fleets were defined as:

Japanese distant water longline, (all 5 areas combined)

Japanese Coastal longline, (area 1 and 2 combined)
Hawaiian longline, (Area 3 and 4 combined)

All CPUE series showed relatively good agreement, describing a generally declining population. The HWN LL and JPN C LL series show good agreement at the end of the time period with the JPN DW LL series that CPUE continued to decline.

Proportion at Lengths
Numbers-(proportion) at-length data were available for 14 of the 25 fisheries (1121 total observations). All fisheries, except EPO purse seine, primarily capture fish between 100-200cm. (Figure 3). The EPO purse seine catch was generally 150-250 cm. New to this assessment is that the JPN DWLL fleet was broken into Commercial and Training fleets. The training vessels fleet measured all fish and thus has smaller fish in the biological samples. Ninety six length bins were defined as 2cm bins from 80-270cm and used to estimate population dynamics.

Assessment Model

In this section we describe the assessment models used. As requested by the WG in the November 2006 meeting, sensitivity analyses were performed using 2 different starting periods. The first model (Full Timseries) was started in 1952 with an equilibrium catch of 75,000 fish (note: sensitivity analysis is done to the assumed historical catch). The second model (Reduced Timeseries) was started in 1964 with an equilibrium catch of 75,000 fish.

Model Structure
A BH S/R function was used, where the steepness of the S/R curve (h) was analogous to the intrinsic rate of increase in a surplus production model. An estimate of $R0$ (unfished recruitment) was also estimated and this was analogous to the carrying capacity. In the base model steepness was fixed at h=0.7. Natural mortality was fixed at M=0.3, growth was estimated (reasons given in discussion). The growth and survival patterns were assumed to be the same for both sexes, thus the model was a single sex model. The variability of recruitment was characterized by the standard deviations of the recruitment deviations (σ=0.5), and σ was fixed at a level consistent with the variability seen in early model runs. In the period prior to the onset of estimation of recruitment deviations (1960 Full Timeseries and 1964 Reduced Timeseries), the recruitment was drawn from the S/R curve. As mentioned above, the population was assumed to be in an equilibrium state prior to 1952 at an exploitation level of 75,000 fish (assumed to occur in JPN DWLL area 1).

Fishery length data was used to estimate selectivity patterns, which control the size (and age) distribution of the removals. The model was setup as an annual model with 4 equal seasons. CPUE was assumed linearly proportional to available biomass, with constant catchability and assumed to occur halfway through season 3. We modeled ages 0-15, with the last bin (age 15) acting as an accumulator. For both CPUE and proportion at length data, the originally inputted SE and effective N values were iteratively re-estimated using a process originally described by McAllister and Ianelli (1997). We assumed catch was known without error and removed half way through each season. A maximum exploitation rate of 0.9 was assumed, with the model penalizing the likelihood for excessive exploitation levels. Likelihood λ's and iterated effective sample sizes or CV are in Table 1.

Likelihood Components:

<u>3 CPUE (treated as surveys) by fleet (assumes lognormal error structure)</u>
HWN LL (1991-2003)
JPN DW LL (1964-2004)
JPN C LL (1994-2004)

<u>14 proportion-at-length series (assumes multinomial error structure):</u>
Area 1 JPN DW LL (1970-2004)
Area 2 JPN DW LL (1970-2003)
Area 3 JPN DW LL (1970-2003)
Area 4 JPN DW LL (1970-2002)
Area 5 JPN DW LL (1970-2002)
Area 1 JPN training (1971-2005)
Area 2 JPN training (1970-2005)
Area 3 JPN training (1970-2004)
Area 4 JPN training (1970-2005)
Area 5 JPN training (1970-1983)
Area 1 JPN driftnet (1972-2001)
Area 3 HWN LL (1994-2003)
Area 4 HWN LL (1994-2003)
EPO Area 5 Purse seine (1991-2004)

Selectivity patterns
Because proportion-at-length information was available for 14 of 29 fisheries, we assumed that the selectivity patterns of the other 15 fisheries mirrored the JPN DW LL fishery selectivity pattern from the same area. This was not true for the area 5 recreational and Costa Rican fleets, which we assumed mirrored the EPO purse seine data. The CPUE series were treated as surveys with selectivity patterns equivalent to its fishery or in the case of the JPN CLL the JPN DWLL. The following is a list of the fishery with length data followed by the fisheries assumed to have the same selectivity pattern. All selectivity patterns were allowed to be domed (double normal) except the Area 5 recreational and Costa Rican fisheries which were characterized by a flat topped selectivity (logistic). All selectivity patterns are assumed constant across time, thus one pattern is estimated for each fishery. All selectivity patterns were estimated as length-based as these were the units of observation. Each fishery with data is given followed by each fishery we assumed to have the same selectivity pattern. *Note the area 5 EPO purse seine is not a specified fishery but only length observations.*

Area 5 EPO purse seine- recreational, Costa Rica
Area 3 Hawaiian longline (HWLL)
Area 4 Hawaiian longline
Area 1 Japanese driftnet (JPN DFTN)
Area 1 Japanese distant water longline- Japan coastal longline (JPN CLL), Taiwan, Korea, Other
Area 2 Japanese distant water longline - Japan coastal LL, Taiwan, Korea, Other
Area 3 Japanese distant water longline- Taiwan, Korea, Japan dfnt,
Area 4 Japanese distant water longline-Taiwan, Korea
Area 5 Japanese distant water longline- Taiwan, Korea
Area 1 Japanese training
Area 2 Japanese training
Area 3 Japanese training
Area 4 Japanese training
Area 5 Japanese training

Convergence Criteria

The model was assumed to have converged if S.E. of the estimates could be derived from the inverse of the negative hessian. We also consider excessive CV's on estimated quantities as indicative of a non-converged model. The correlation matrix was investigated for problematic correlations (or lack of correlations). Parameters found to have been estimated at a bound was also considered a diagnostic of a non-convergence. Finally, the base model was run several times with different initial values of key parameters (ex. R0) and different phasing for things like growth to determine if a global minimum was located.

Sensitivity Runs

Results of the following sensitivity runs using both models are presented in a table in the sensitivity section to examine the effects of key assumptions. The change from the base model is given.

1) M=0.2
2) M=0.3
3) M=estimated
4) h=0.5
5) h=0.6
6) h=0.8
7) h=0.9
8) h=estimated
9) Equilibrium catch=150,000 fish
10) Equilibrium catch=38,000 fish

Sensitivity analysis completed but not included in the document.
11) 9 cpue (area specific CPUE)
12) removal of area 5 PS data

Modeling Results

Note: because of limited time and nearly identical fits between starting the model in 1952 and 1964 only results for the base model for the full (1952) time series are given in the figures. The table of likelihood and parameter estimates details the results of the reduced model runs.

Model Fits and performance

All models had a relatively good statistical fit to the JPN DW LL CPUE series, which apriori was considered the primary tuning index (Figure 4). A reasonable fit the JPN DW LL CPUE series and was also the primary visual diagnostic of model performance. The fit to the JPN CLL and HWLL series appear reasonable, however the short time span and the variability make judging fit difficult. We note that the model predicts the high observed values in the early part of the JPN DWLL cpue were the result of higher than normal recruitment just prior. We show in Figure 4 the 1962 and 1963 values which were not used in the fitting (WG decision Nov 2007) but indicated a smaller population and they appear to agree with the models estimates.

Proportion at length data was variable, however the model fit to the proportion-at-length data also appeared reasonable (Figure 5).

Estimated Selectivity Patterns

The estimated selectivity patterns are given in Figure 6. As expected the Training vessels selected for smaller fish than the DWLL fleet. This is likely due to the fleet not retaining smaller fish. The effect is most dramatic in the southern areas. The HWLL fleet also selected for smaller fish, and this is likely because the data was from the observers and not the market samples. Finally the EPO PS selectivity was strongly right-shifted (towards larger fish) as expected.

Estimated Time Series

Modeled exploitation rates appear to be highest in area 1 (Figure 7), with some estimates approaching 40% in 1 year. Estimated recruitment declined over the time series to account for the diminishing CPUE described by the JPN DW LL series. The model also estimated that spawning biomass declined over the timeseries (Figure 8).

Sensitivity

The likelihood values and estimated parameters of all sensitivity analyses are given in Tables 2 and 3 (Full Timeseries) and 4 and 5 (Reduced Timeseries). The sensitivity results show that increase productivity via larger h or M show a smaller but less depleted population. Contrasting, less productive populations start from a larger initial size and end up more depleted. The model adjusts the growth parameters partly to compensate, but in all cases the estimated growth indicates a large asymptotic size than given by Melo-Barrera et al. (2003).

Retrospective

Not done due to time constraints.

Bayesian Results
Due to time constraints no Bayesian results are provided.

Forecasting and MSY
No forecasts or estimates of MSY are given.

Discussion

Given the small amount of time between receiving final data and the due date of this document we did not explore all potential model parameterizations. During the early stages of modeling we tried to estimate all selectivity parameters, but these models showed sensitivity to starting values and phasing. This suggested that it was likely the models were slightly over parameterized. Therefore we fixed the width of the selectivity peaks and the model appeared to perform much more consistently. In the full timeseries model we have estimated recruitment back to 1960 (1964 in the reduced model). Examination of the estimated standard deviations of the recruitment deviations suggests that significant information on recruitment does not occur until slightly later. The proportion at length data does not start until 1970 suggesting that there may be little information about age-classes older than a few years in these data. This is an area for further model consideration.

The model is estimating growth (rate *k* and maximum size). We felt this was needed not only because growth is not consistently estimated in the outside studies, but also because the EPO PS data was much larger than our growth studies. It was not realistic to fix maximum length at <200cm when the PS proportion at length data suggests that most of the fish in that area are 20-30% larger. If the PS data were removed, it appears that the estimates from Melo-Barrera et al. (2003) would be reasonable. It is also quite likely that removal of the PS data would allow the estimation of much less peaked selectivity patterns for the other fisheries. We would suggest in a model that removes PS data that the JPN DFTN fishery be assumed asymptotic. Another solution to the PS data is to assume it was measured in LJFL and transform it to EFL. We have done this at it appears to be similar in size composition as the other fisheries. However, investigation of this potential by IATTC staff did not show any evidence that the samples were collected as LJFL. Thus the data were left as is. The WG should give consideration to this area as the PS data control selectivity and growth parameters in this model (ie greatly affect any resulting MSY calculations). It may also be possible to estimate the size at age-1 internally; this may be a worthwhile option to explore.

We also attempted to estimate both *h* and *M*. Models with *M* estimated did not always converge, although when they did they indicated that a higher mortality rate was preferred. However, models that estimated h usually converged to smaller (less resilient) estimates of h. Given the 'one way trip' modeled in the assessment we do not advocated estimating either parameter in the final assessment.

We also note that further work should be done on which fisheries are allowed to take age-0 fish. It can be problematic to allow significant catch of age 0 fish in the model as natural mortality may be quite different from the assumed constant. This could adversely affect the estimation of abundance for other age classes. We have tried to minimize this by restricting the majority of the fisheries and catch to selectivity patterns constrained by the age-selectivity pattern to not take age-0 fish. We do note that because catch is recorded as numbers not weight we do not have a problem in removing the right numbers due to binning at 80cm. This is an area for further consideration.

We made several assumptions on selectivity. First, that the selectivity of the JPN DWLL fleet area 1 was the same as the CPUE derived from JPN DWLL area 1-4. The similarity of the selectivity patterns of the fleet across area 4 indicates that this may be reasonable. Furthermore, area 1 contained the majority of the catch. Second, we assumed that all fisheries without biological samples had the same selectivity pattern as the JPNDWLL fleet. In some instances (example JPN DFTN area 2), a selectivity pattern from the same gear but a different area may be a better substitution. This is an area of consideration for the WG.

Several historical (equilibrium) catches were assumed. The average total catch in the 1950's was between 150-180 thousand fish. It is quite likely that catches in the 1940's were very minimal during WWII and that for the relatively short-lived marlin that the population was lightly exploited. Thus, if starting the model in 1952 assuming a lightly exploited population (38 or 75 thousand fish) may be more realistic. If starting the model in 1964 then a more heavily exploited population (historical catch 150 thousand fish) may be more realistic. Further work on true historical catches is warranted, however results do not appear to be very sensitive to this assumption.

Overall, the sensitivity results (likelihood profiles) indicated that the model was performing as expected. If you increase the population productivity assumptions the model predicted a smaller, less depleted population, and vice versa. All models indicated that striped marlin is at low population levels. Given that the index of abundance declined by ~90%, this was expected. It may be that the index of abundance shows some hyper-depletion, however catches of striped marlin have also declined which supports the assertion that population levels are low.

Literature Cited

Fridmodt, C., 1995. Multilingual illustrated guide to the worlds commercial warmwater fish. Fishing News Books, Osney Mead, Oxford, England. 215p.

Heidelberger, P. and P.D. Welch. 1983. Simulation run length control in the presence of an initial transient. *Operations Research* 31: 1109-44.

Hinton, M.G., and M.N., Maunder 2003. Status of striped marlin in the eastern Pacific Ocean in 2002 and outlook for 2003-2004. IATTC Assessment Report p 287-310.

Holdsworth, J., and P. Saul. 2004. New Zealand billfish and gamefish tagging, 2002-2003. New Zealand Fisheries Assessment Report. 2004/50, 27p.

Geweke, J. 1992. Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments. pp. 169-93. In: Bayesian Statistics 4 (eds J.M. Bernardo, J. Berger, A.P. Dawid and A.F.M. Smith.) Oxford University Press, Oxford.. Bureau of Resource Sciences, Canberra, Aus. 422p.

Kailola, P.J., M.J., Williams, P.C. Stewart, R.E. Reichelt, A., McNee and C. Grieve. 1993. Australian Fisheries resources

McAllister, M.K. and J.N. Ianelli 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. *Canadian Journal of Fisheries and Aquatic Sciences* 54: 284-300.
Melo-Barrera, F.N., Uraga-Felix, and C., Velasquez-Quinonez, 2003. Growth and length-weight relationships of the striped marlin in Cabo San Lucas, Baja California Sur, Mexico. Ciencias Marinas 29(3):305-313.
Merrett, N. 1971. Aspects of the biology of billfish (Istiophoridae) from the equatorial western Indian Ocean. J. Zool. Lond. 163:351-395.
Methot, R.D., and I. J. Stewart. Status of the U.S. canary rockfish resource in 2005. Appendix in Pacific Fishery Management Council. Status of the Pacific Coast groundfish fishery through 2005 and recommended acceptable biological catches for 2007: stock assessments and fishery evaluation. Pacific Fishery Management Council, Portland, Oregon.
National Research Council, 1998. Improving fish stock assessments. National Academy Press. Washington D.C. 177p.
Piner, K.R., E.J., Dick, and J. Field. 2005. Stock Status of Cowcod in the the Southern California Bight and future prospects. Appendix in Pacific Fishery Management Council. Status of the Pacific Coast groundfish fishery through 2005 and recommended acceptable biological catches for 2007: stock assessments and fishery evaluation. Pacific Fishery Management Council, Portland, Oregon.
Piner, K. R., M. Schriripa, J. Rogers, T. Builder, and R. Methot. 2000.Status of Bank rockfish off California 2000. Appendix in Pacific Fishery Management council. Status of the Pacific Coast groundfish fishery through 1999 and recommended acceptable biological catches for 2001: stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, Oregon.
Skillman, R. and M. Young. 1976. Von Bertalanffy growth curves for striped marlin, Tetrapterus audax and blue marlin, Makaira nigricans in the North Central Pacific. Fish. Bull. 74(3):553-566.
Van der Elst., R., 1981. A guide to the common sea fishes of southern Africa. C. Struik, Cape Town. 367 p.
Wares, P.G., and G.T. Sakagawa, 1975. Some morphometrics of billfishes from the eastern Pacific Ocean. P. 107-120. In R.S. Shomura and F. Williams. (eds) Proceedings of the international billfish symposium, Kailu-Kona, Hawaii. August 1972, part 2. Review and contributed papers. U.S. Dep. Commer. NOAA Tech Rep. NMFS SSRF-675.

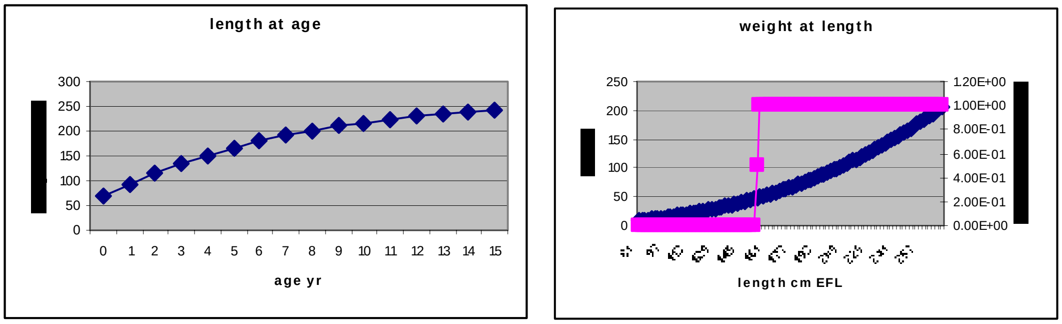


Figure 1. Basic Biology used in the assessment model 1) model estimated (base Full Timeseries) length at age and 2) fixed weight at length and proportion mature at length.

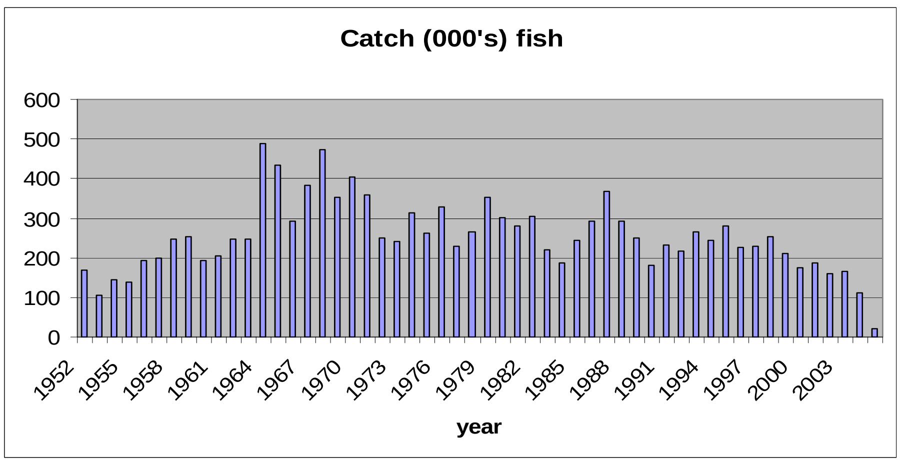


Figure 2. Total annual catch of striped marlin (numbers) in the North Pacific Ocean by fleet.

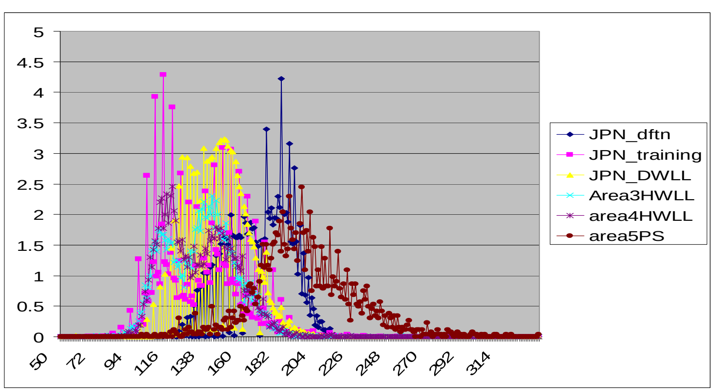


Figure 3. Length distribution of each gear (summed across year, quarter and areas)

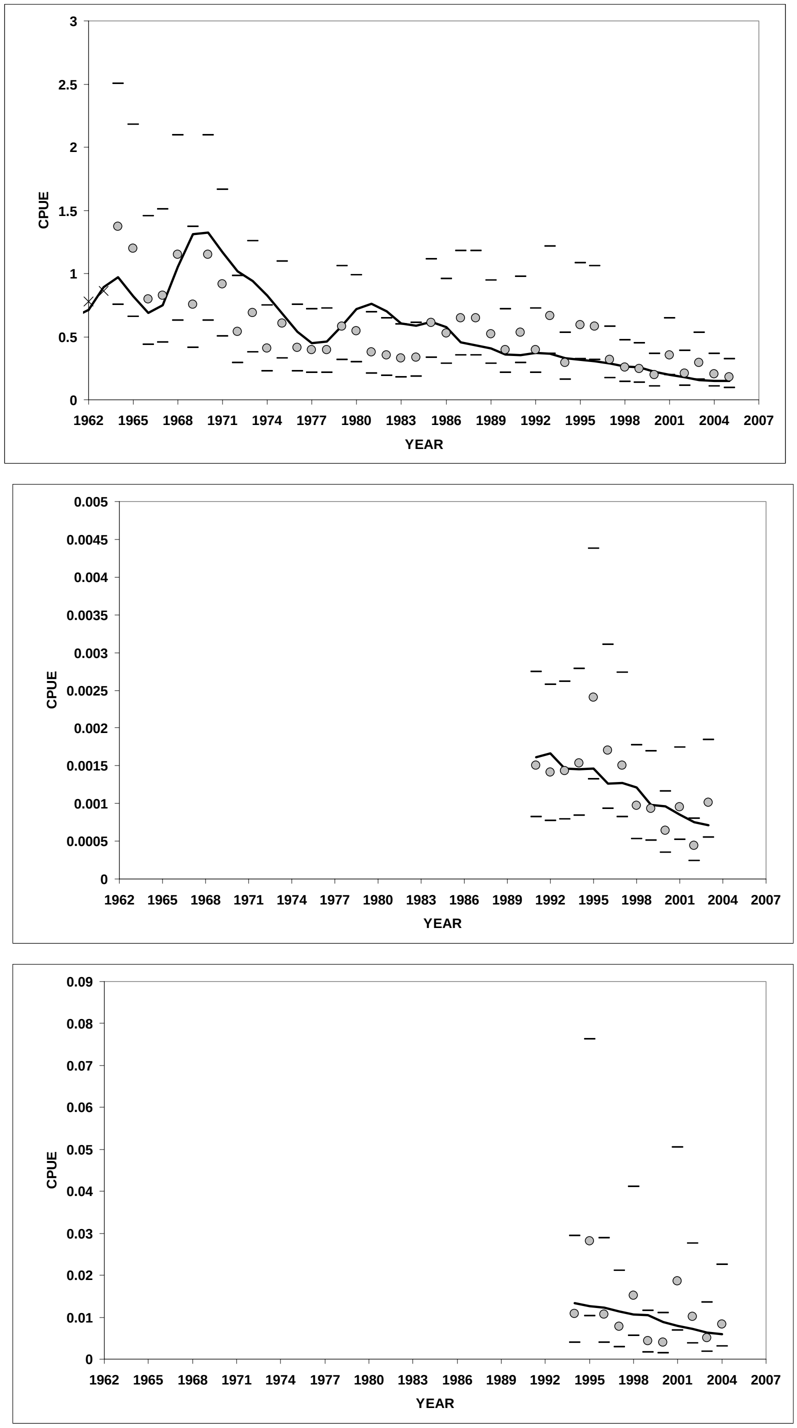
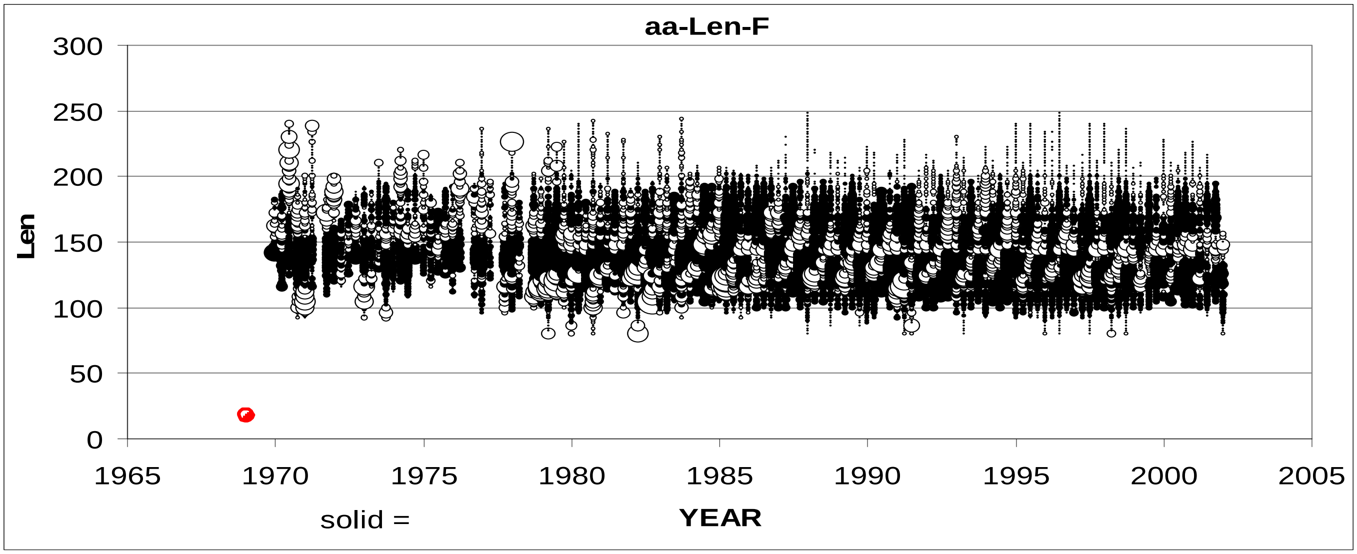
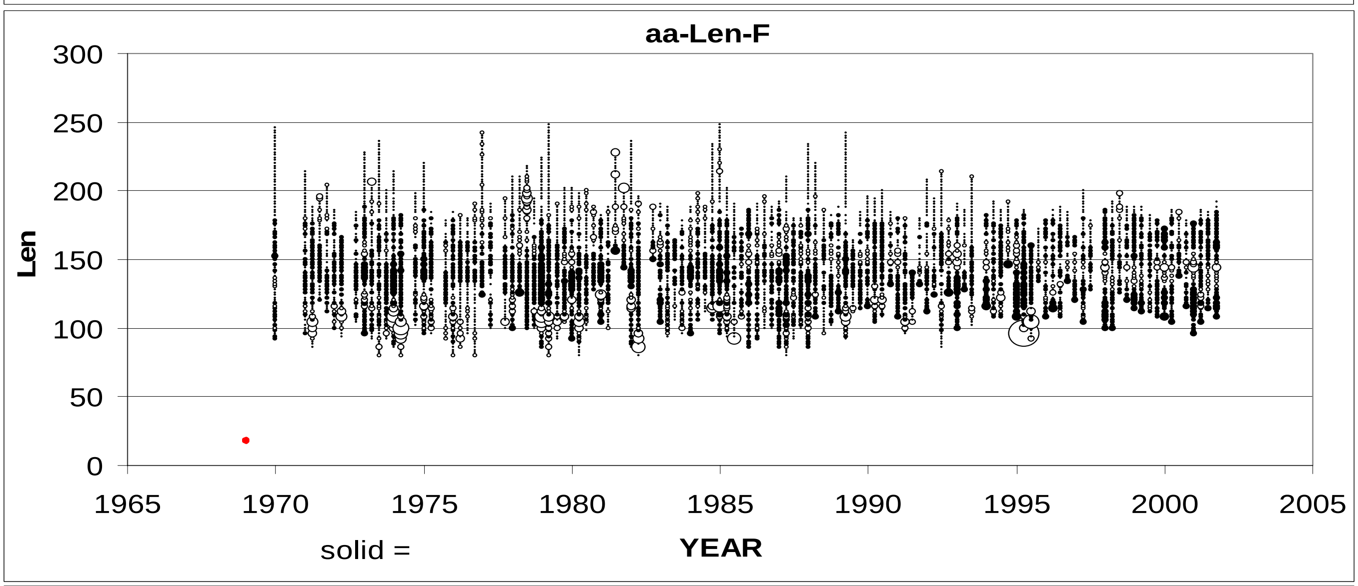
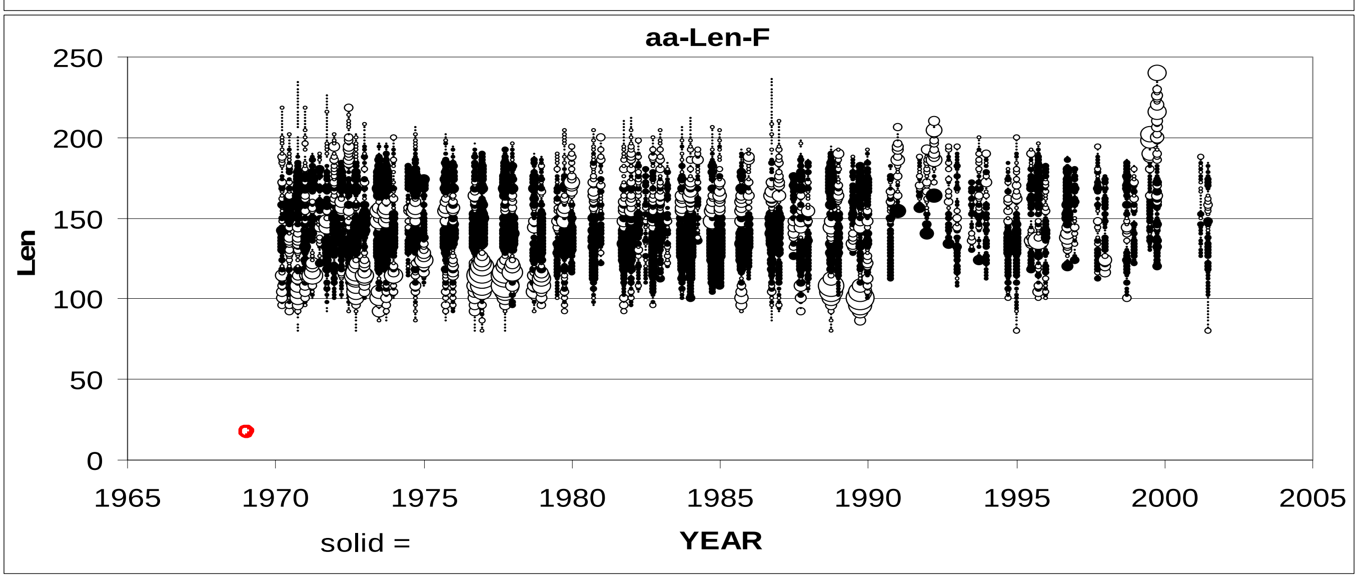
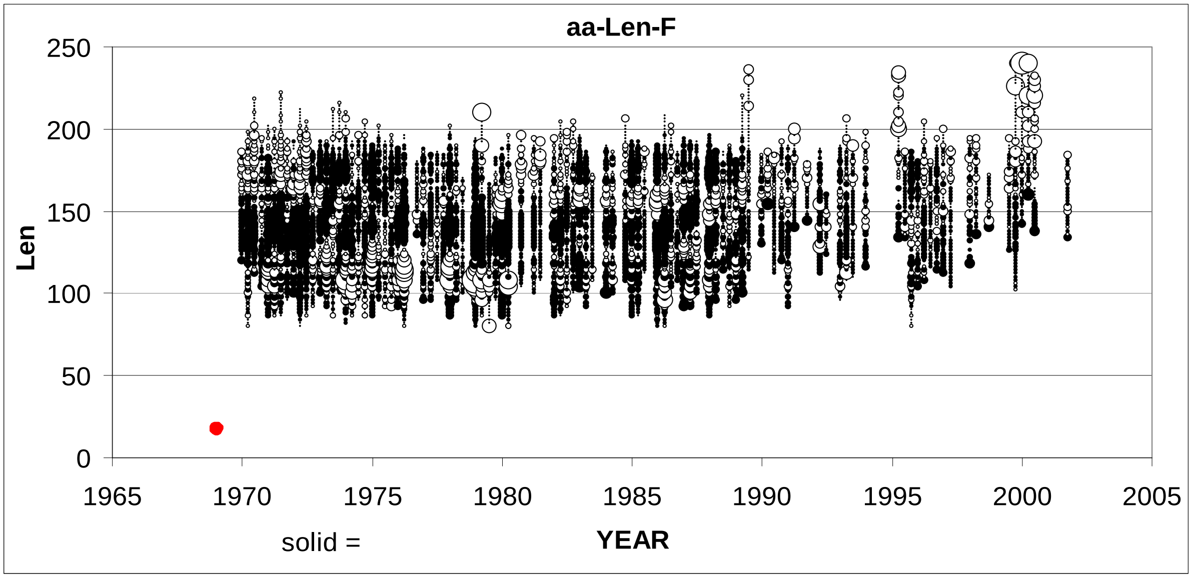


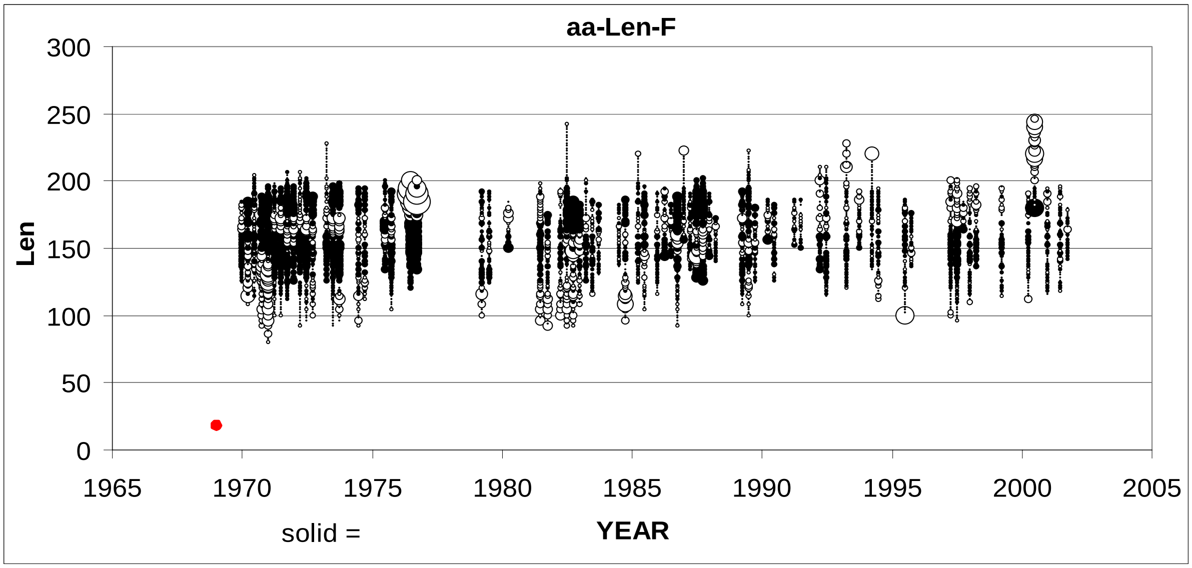
Figure 4. The fit to each CPUE series 1) JPN DWLL, 2) HWN LL and 3) JPN CLL. Circles represent the observed CPUE, the line is the model estimate and bars are 95% Confidence intervals around each observed point. In the JPN DWLL series the 1962 and 1963 observations are shown (x) but not used in the likelihood. Note they are higher above than below the observed value because the assumed error distribution was lognormal.

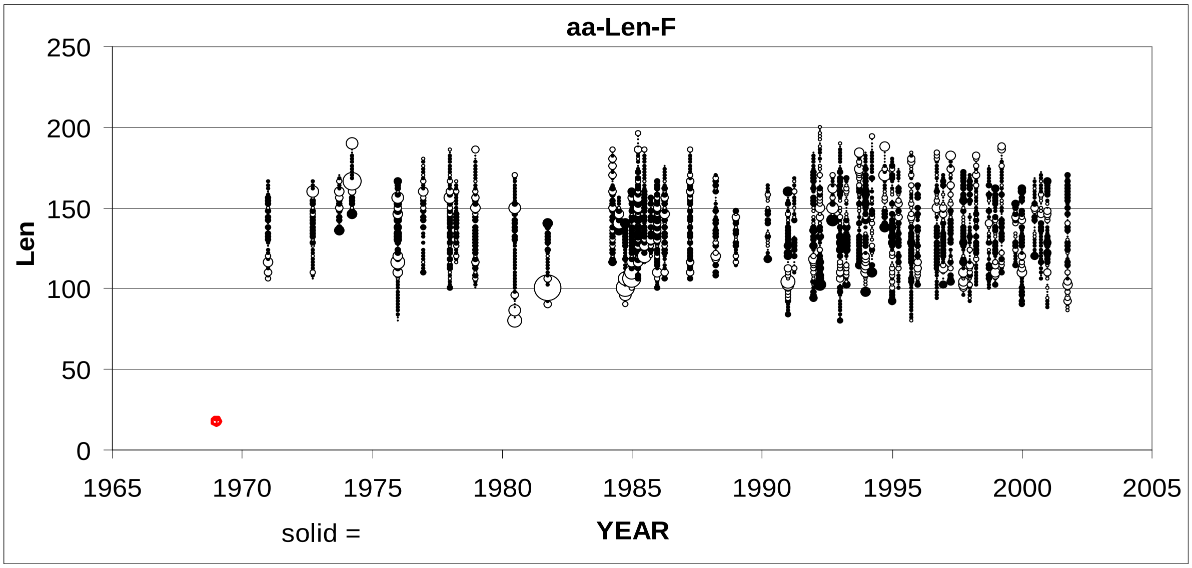

aa-Len-F
300
250
200
150
100
50
0
Len
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR

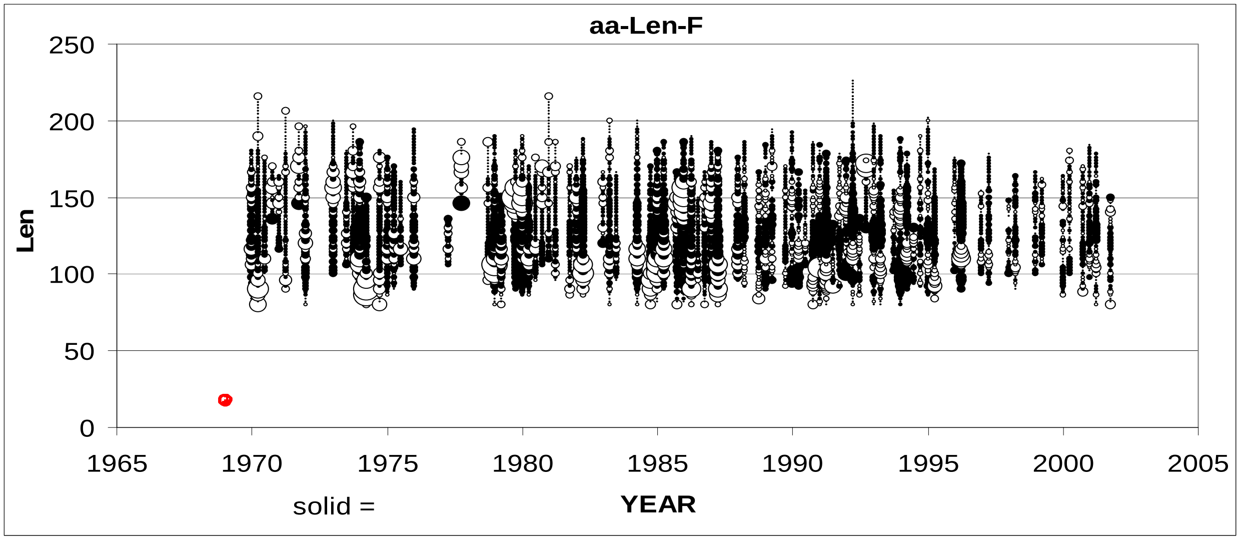

aa-Len-F
300
250
200
150
100
50
0
Len
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR

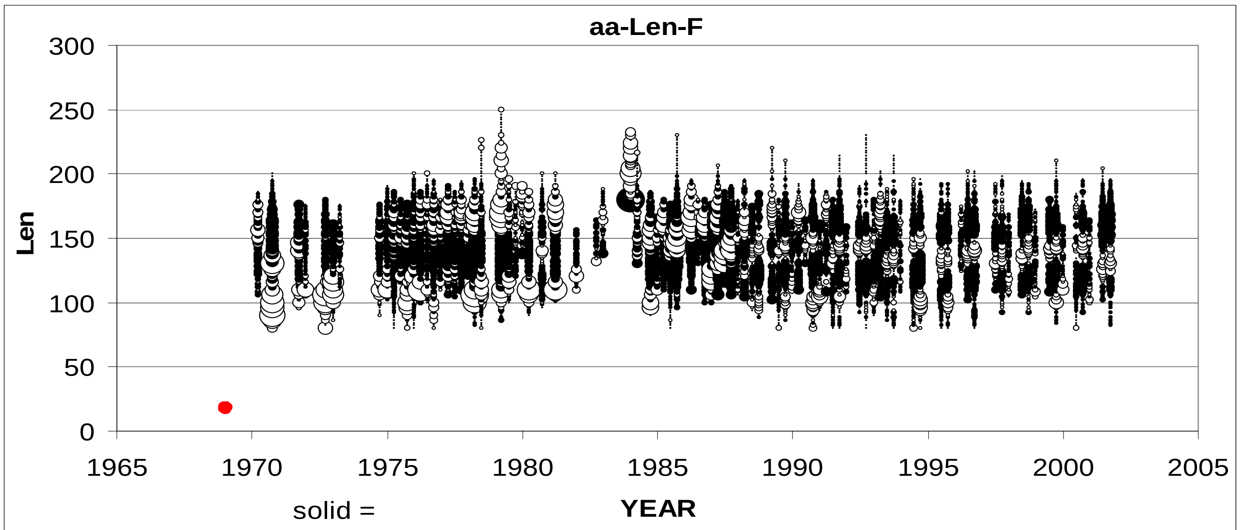

aa-Len-F
250
200
150
100
50
0
Len
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR

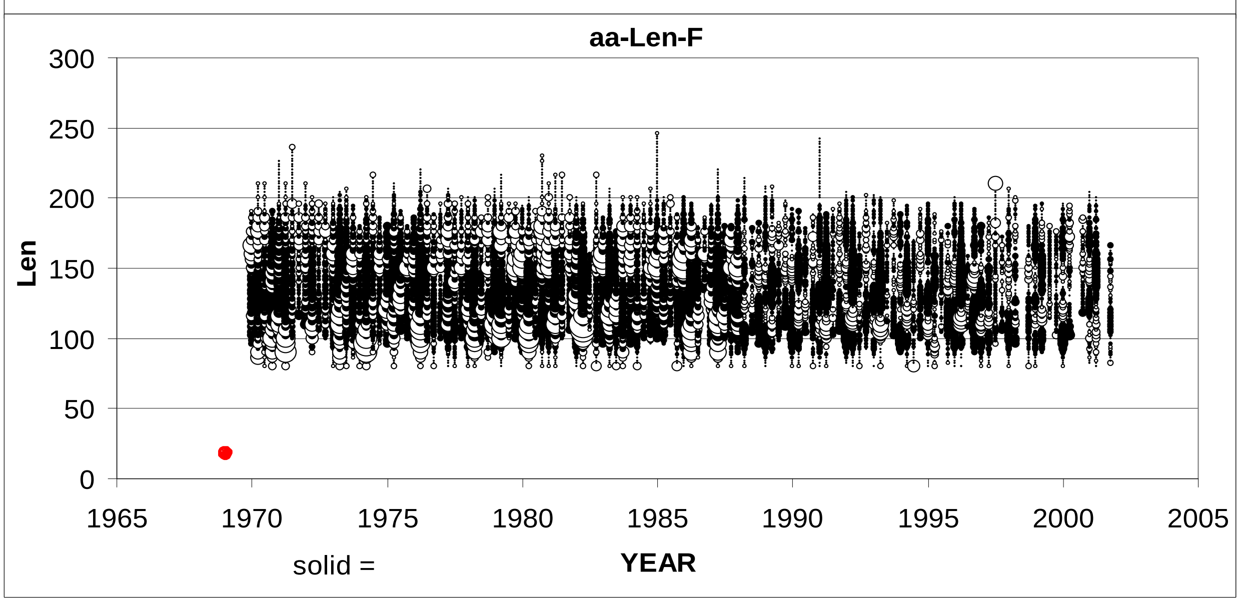

aa-Len-F
250
200
150
100
50
0
Len
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR

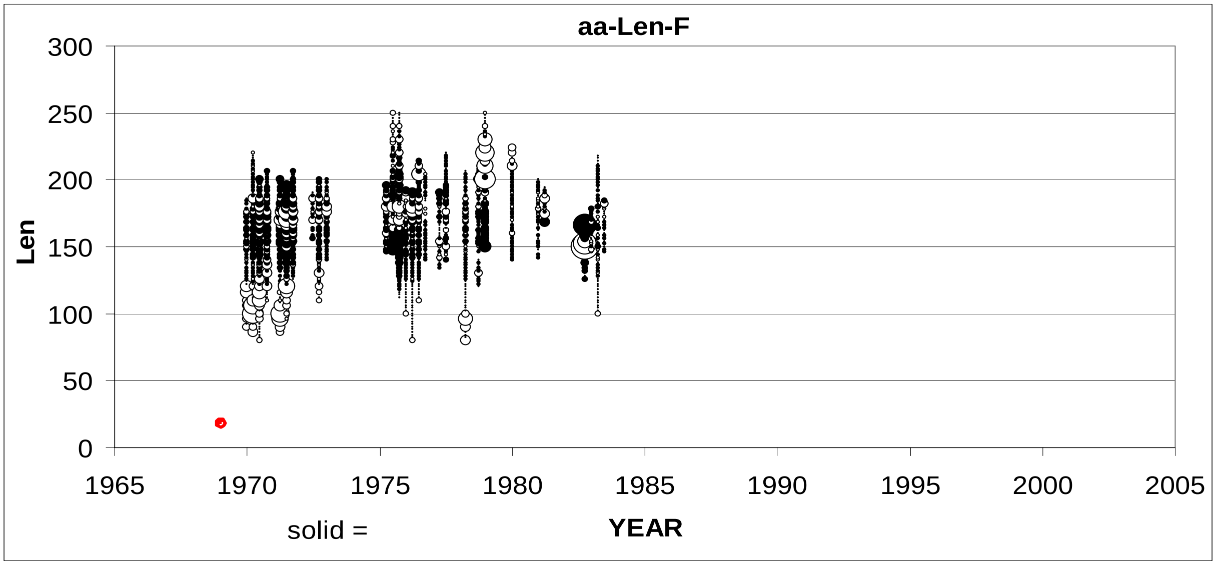

aa-Len-F
300
250
200
150
100
50
0
Len
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR

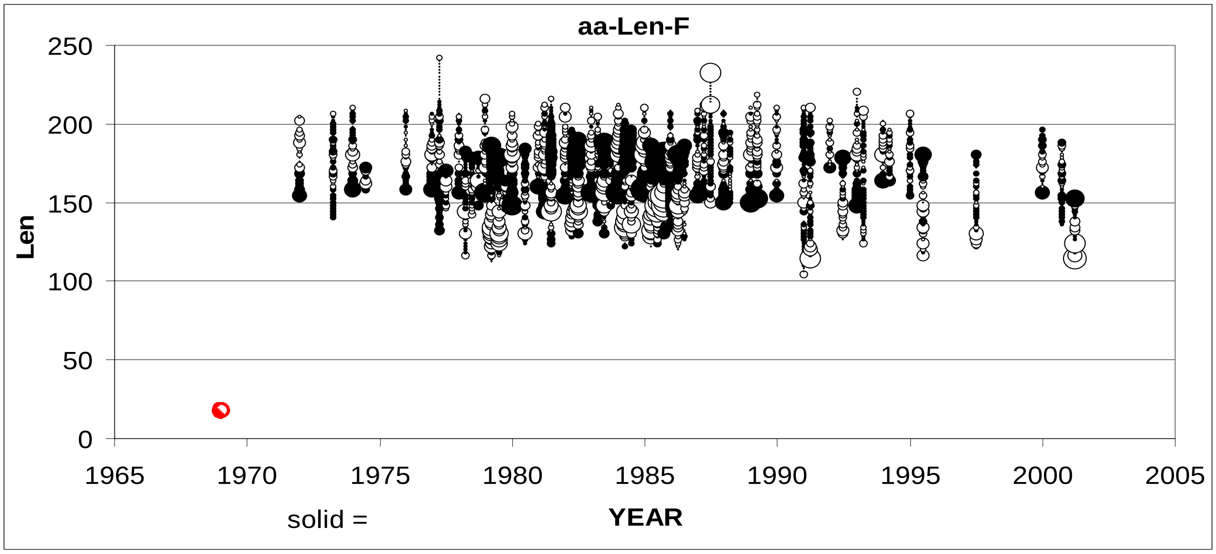

aa-Len-F
250
200
150
100
50
0
Len
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR

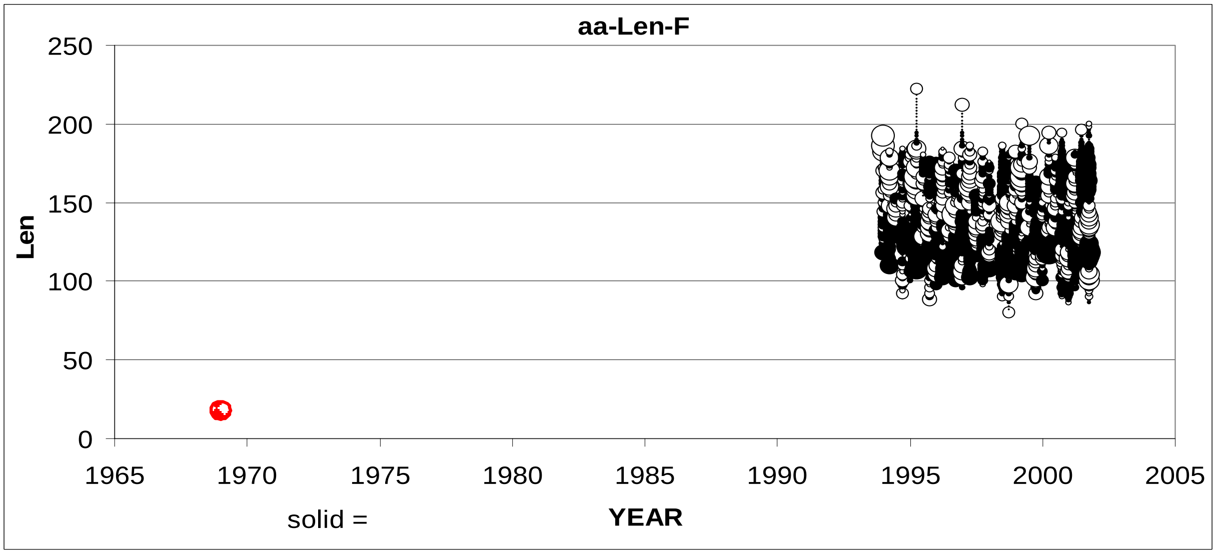

aa-Len-F
Len
250
200
150
100
50
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR

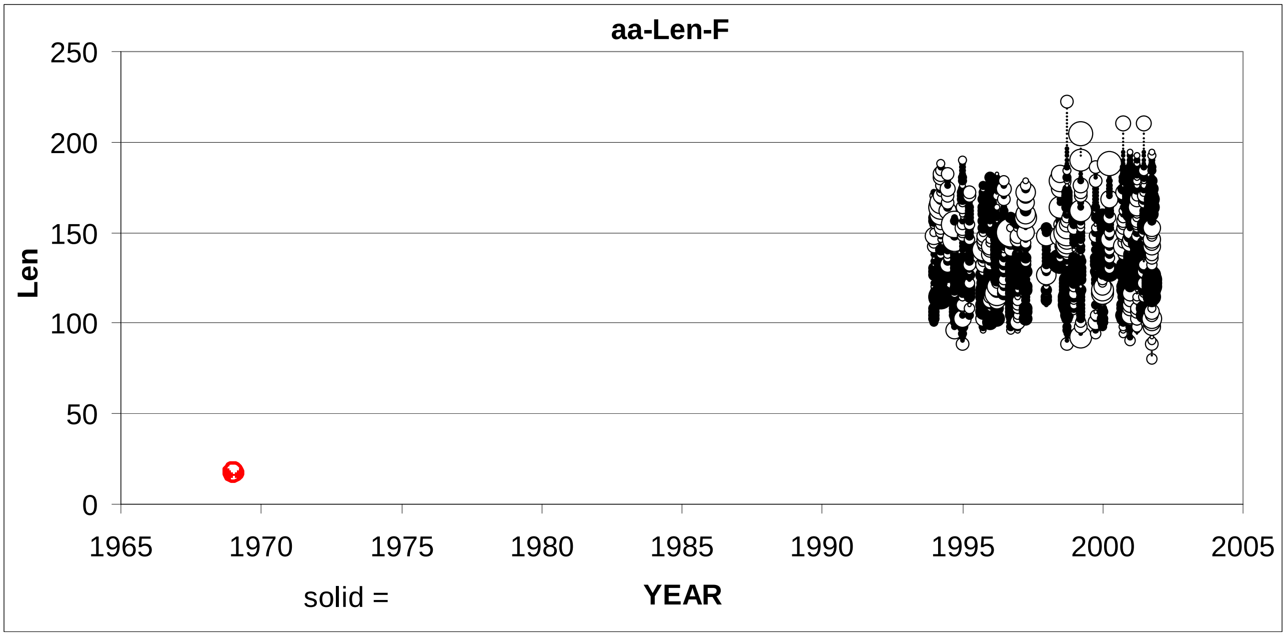

aa-Len-F
Len
300
250
200
150
100
50
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR


aa-Len-F
Len
300
250
200
150
100
50
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
solid =
YEAR


aa-Len-F
Len
YEAR
solid =


aa-Len-F
Len
YEAR
solid =


aa-Len-F
Len
YEAR
solid =



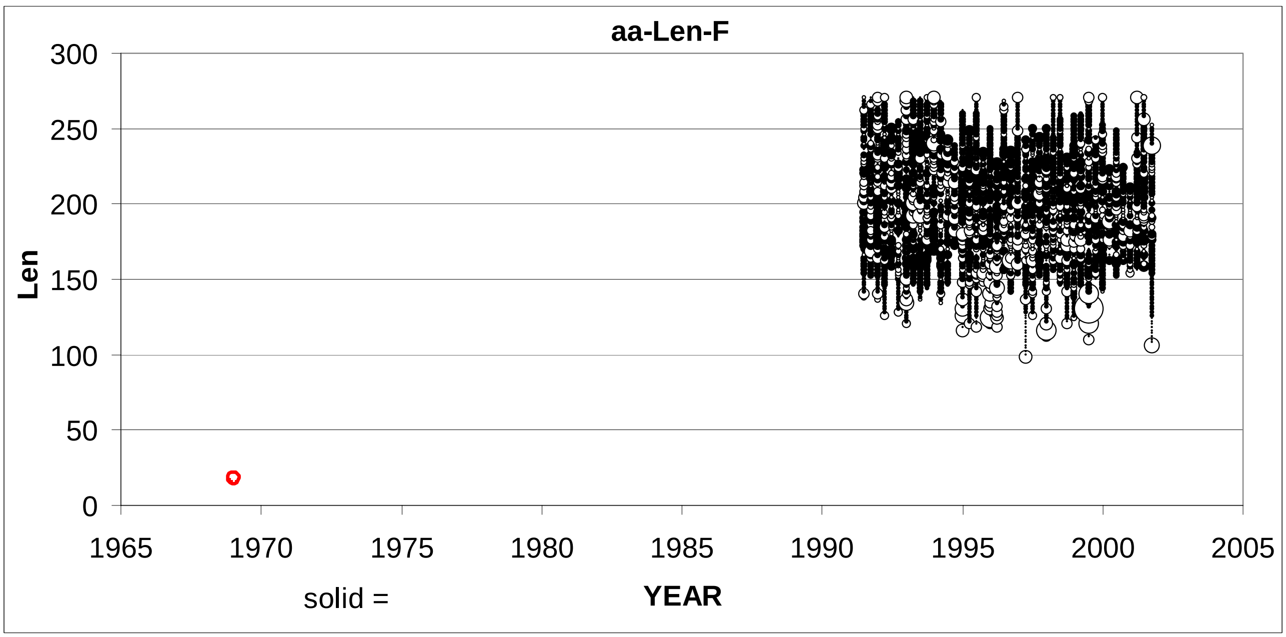


Figure 5. Pearsons Residuals for each fishery (1-14) and quarter (1-4). Solid circles represent negative residual. The 14 fisheries are (in order) JPN DWLL areas 1-5, JPN Training areas 1-5, JPN DFTN area 1, HWN LL area 3-4 and PS area 5.

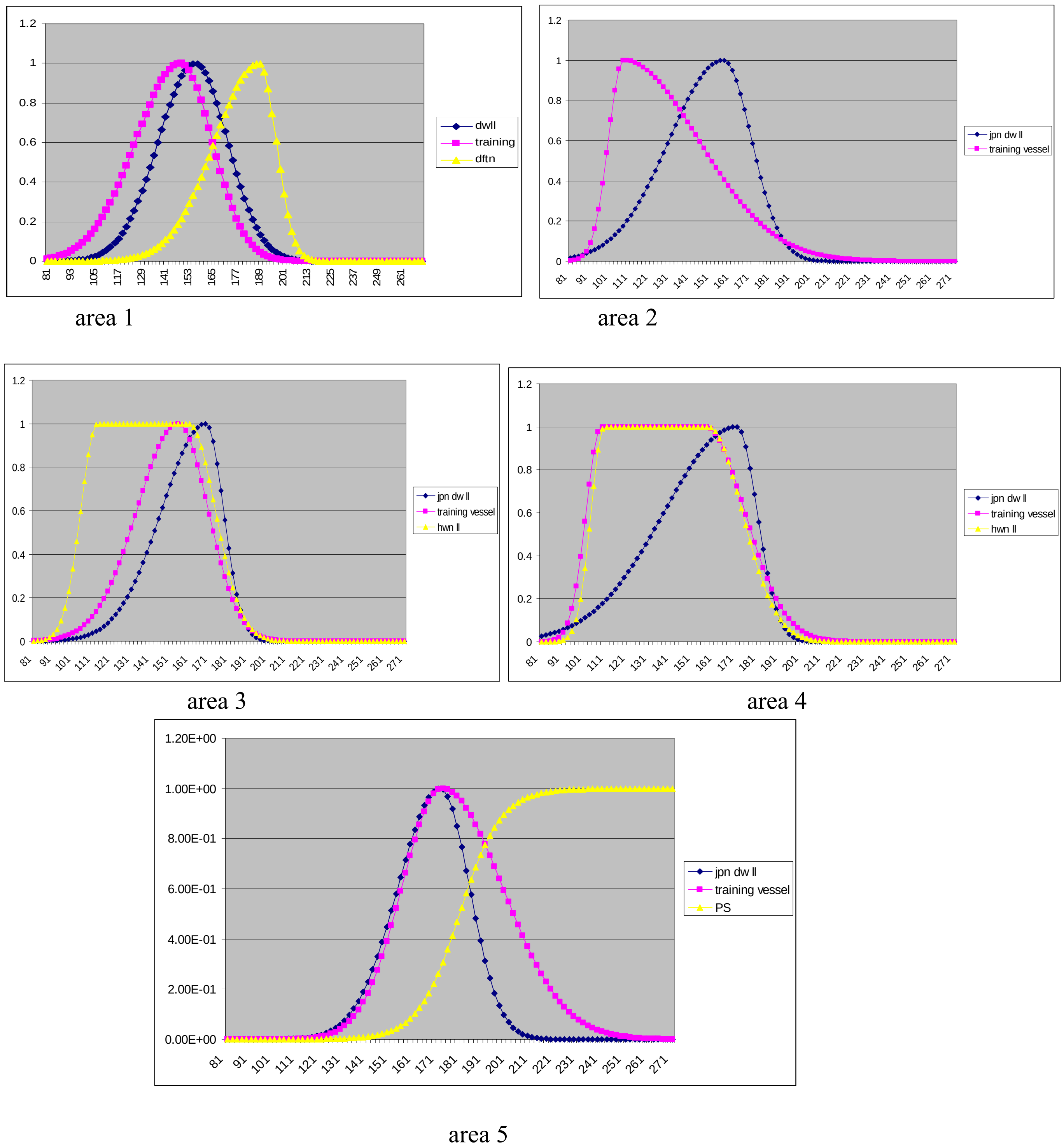


Figure 6. Estimated Selectivity patterns by regions 1-5 (top to bottom and left to right)

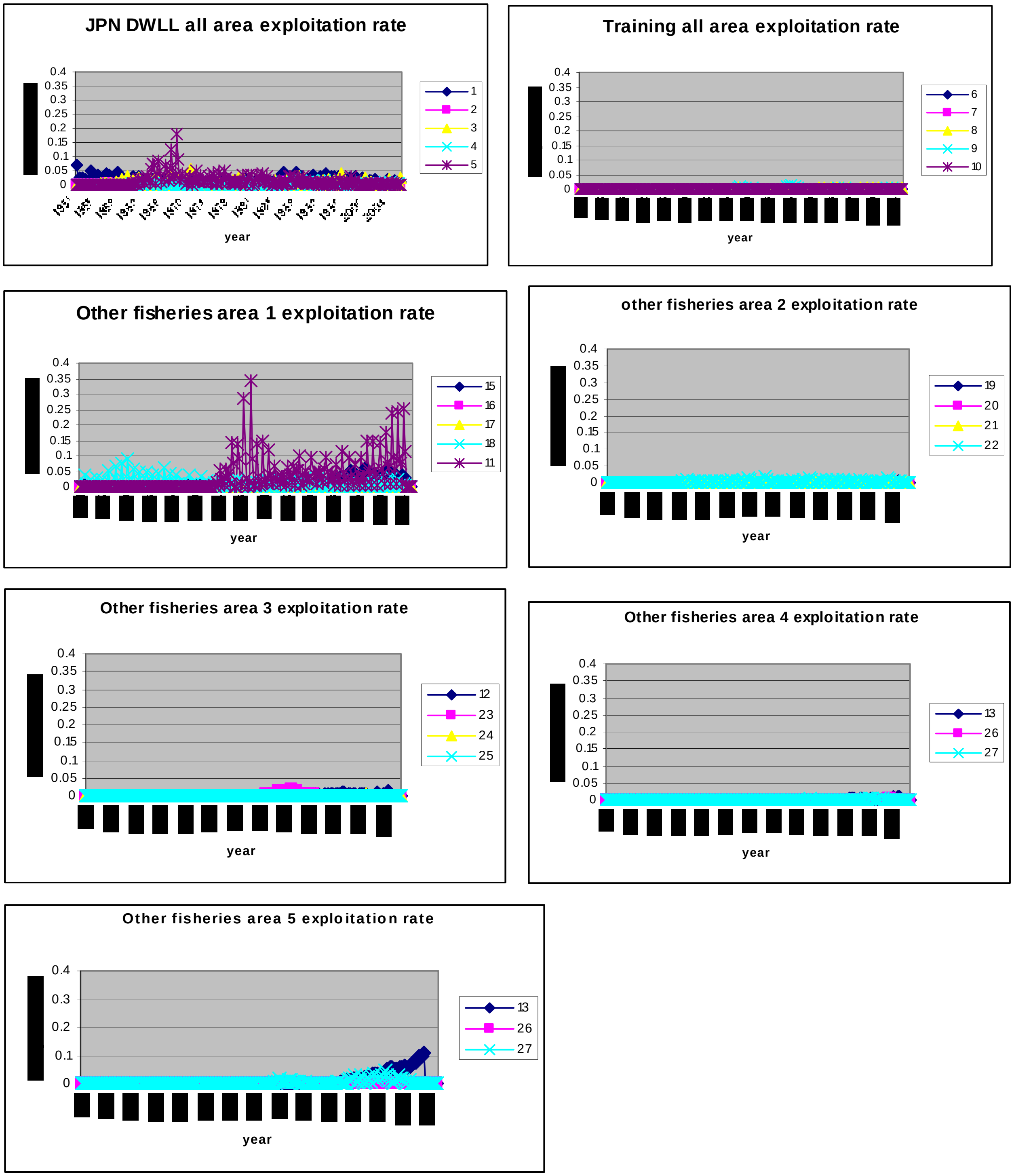


Figure 7. Estimated exploitation rates by fishery and area. All graphs are rescaled so maximum rate is 0.4.

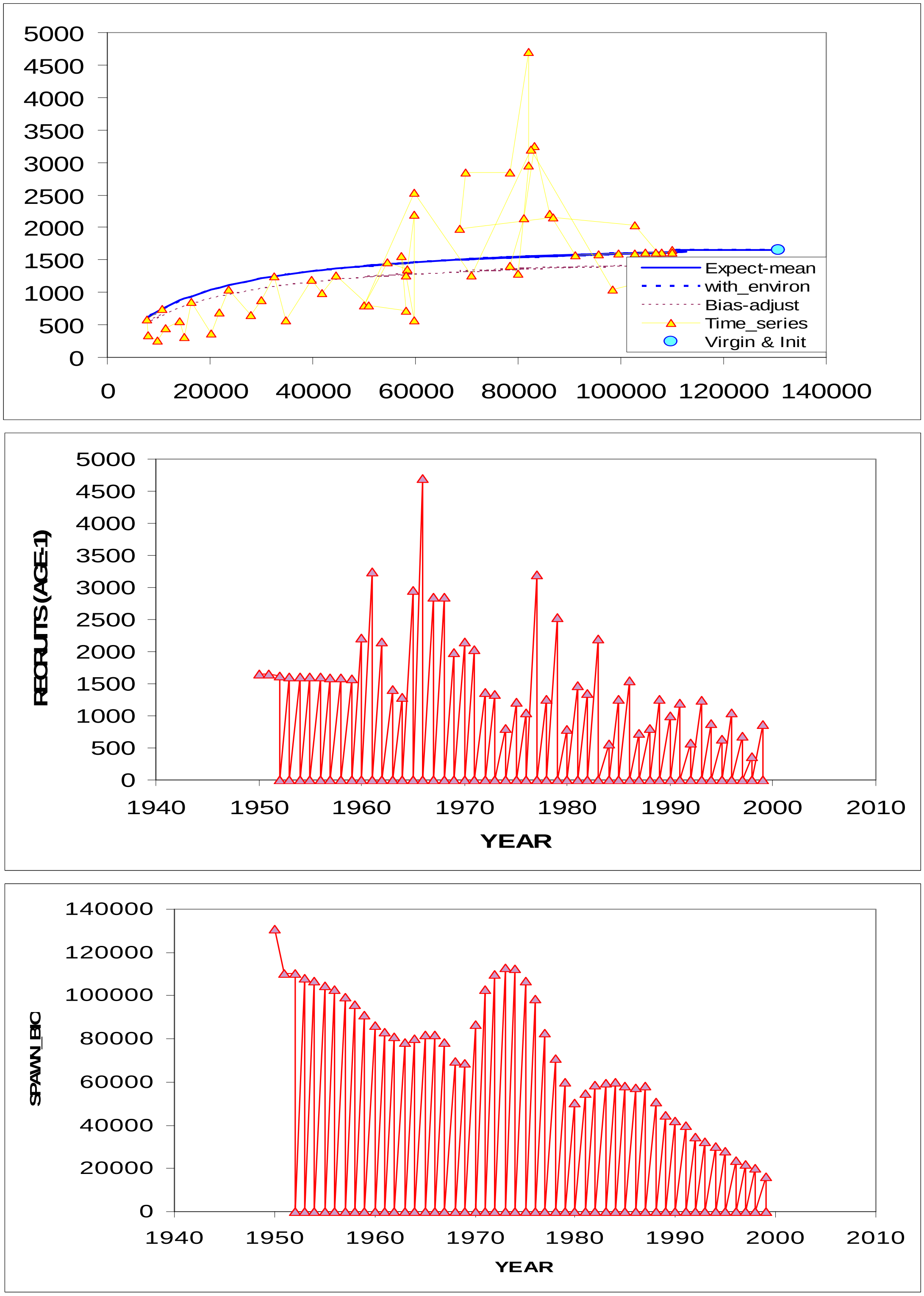


Figure 8. Estimated 1) S/R curve, 2) recruitment pattern and 3) spawning biomass timeseries.

Table 1. Inputted standard deviations and the models estimate for each CPUE series and inputted effective sample sizes and model estimates for the proportion at length observations. The total number of obsevations for each component are also given.

Likelihood Component	#obs	Model Est.	Inputted
CPUE			
JPN DWLL	42[a]	0.382339	0.3
HWN LL	13	0.284408	0.3
JPN CLL	11	0.556042	0.5
Proportion at Length			
JPN DWLL area1	133	82.7331	76.7519
JPN DWLL area2	126	26.7285	25.1429
JPN DWLL area3	84	47.8429	43.7143
JPN DWLL area4	104	36.7026	29.5769
JPN DWLL area5	75	42.4069	43.2
Training area1	61	23.9556	23.4098
Training area1	96	20.8218	19.9583
Training area1	98	36.0593	39.9796
Training area1	134	35.8631	43.5075
Training area1	29	17.3244	18.5517
JPN DFTN area1	60	19.0612	21.8667
HWN LL area 3	36	41.3288	40.1389
HWN LL area 3	31	45.5429	39.1935

[a] there are 69 observations but 1961, 1962 and 1963 are not used in the fitting.

A blank page that always seems to occur when I introduce tables in landscape format.

Probably indicative of my inability to operate the software.

Table2. Likelihoods Full Timeseries (start 1952). Models that did not converge are recognized by (NC) below heading.

Likelihood component	base	*M*=0.2	*M*=0.4	*M*=est (NC)	*h*=0.5	*h*=0.6	*h*=0.8	*h*=0.9	*h*=est	Equib Catch 150,000	Equib Catch 38000
Area1DWLL len	2613.27	2611.84	2619.47	2635.75	2612.62	2612.73	2614.14	2615.37	2613.23	2613.28	2613.26
Area2DWLL len	1764.55	1767.53	1761.66	1760.2	1763.65	1764.08	1765.07	1765.71	1763.27	1764.55	1764.54
Area3DWLL len	1395.13	1406.88	1387.18	1372.2	1394.7	1395.22	1394.64	1393.75	1392.75	1395.12	1395.13
Area4DWLL len	1443.28	1451.72	1435.58	1411.25	1442.4	1443.2	1442.85	1441.91	1439.87	1443.28	1443.28
Area5DWLL len	1376.67	1369.12	1382.24	1378.11	1377.11	1376.86	1376.49	1376.3	1377.44	1376.67	1376.67
Area1Train len	857.748	857.623	858.471	860.068	857.574	857.644	857.881	858.041	857.571	857.749	857.747
Area2Train len	1447.73	1454.51	1442.94	1439.08	1447.62	1447.68	1447.75	1447.73	1447.51	1447.73	1447.73
Area3Train len	2200.93	2204.11	2203.39	2223.45	2200.59	2200.57	2201.65	2202.78	2201.32	2200.93	2200.93
Area4Train len	4091.43	4123.18	4071.91	4067.04	4090.94	4091.19	4091.69	4091.99	4090.72	4091.43	4091.43
Area5Train len	494.879	492.066	497.824	500.881	495.45	495.079	494.79	494.798	496.167	494.874	494.881
Area1dtn len	733.087	735.666	730.531	725.653	732.992	733.102	732.983	732.786	732.593	733.089	733.086
Area3hwnll len	540.434	532.79	549.09	546.158	540.261	540.441	540.325	540.145	539.635	540.434	540.434
Area4hwnll len	384.944	383.128	387.989	383.803	384.933	384.993	384.822	384.63	384.615	384.943	384.944
Area5EPO len	1120.3	1143.27	1108.87	1122.23	1121.11	1120.42	1120.5	1121.06	1123.63	1120.3	1120.3
DWLL CPUE	-16.4575	-23.3719	-10.4654	-20.0636	-15.425	-15.9654	-17.0025	-17.5978	-14.5079	-16.4616	-16.4558
HWN LL CPUE	-9.80975	-9.83201	-9.46886	-2.84116	-9.82721	-9.83161	-9.74565	-9.60865	-9.79529	-9.80947	-9.80985
CLL CPUE	-0.8226	-0.758	-0.92103	0.17866	-0.70997	-0.75988	-0.89150	-0.95820	-0.69882	-0.82313	-0.82239
total	20429.8	20482.9	20417	20395.2	20420.5	20424.8	20434.8	20439.5	20418.2	20429.8	20429.7

Table3. Key Parameters and Derived quantities Full Timeseries (start 1952). Non-converged models (NC) will not have estimated std. Estimated parameter values are bolded.

	base	*M*=0.2	*M*=0.4	*M*=est (NC)	*h*=0.5	*h*=0.6	*h*=0.8	*h*=0.9	*h*=est	Equib Catch 150,000	Equib Catch 38,000
B0 (t)	130656	208396	112618	5.46E+09	177913	147889	120016	113547	237838	130860	130567
B0 std	3.80E+03	6.03E-02	7.83E+03	3.47E+10	5.59E+03	4.39E+03	3.86E+03	4.35E+03	3.54E+04	3.79E+03	3.80E+03
2005 6Spawn biomass (t)	10650.7	8341.69	16502.6	3.66E+09	9787.15	10054.9	11602.1	13053.3	10180.8	10655.7	10648.7
2005 Spawn Std	2.08E+03	6.03E-02	4.96E+03	2.32E+10	3.09E+03	1.94E+03	2.32E+03	2.71E+03	2.10E+03	2.08E+03	2.08E+03
k	**229.006**	**222.198**	**236.184**	**240.641**	**228.775**	**228.988**	**228.905**	**228.703**	**228.111**	**229.006**	**229.007**
Lmax (EFL cm)	**0.135351**	**0.150813**	**0.120807**	**0.111013**	**0.135654**	**0.135362**	**0.135501**	**0.135788**	**0.136636**	**0.135353**	**0.13535**
M	0.3	0.2	0.3	**0.438456**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
h	0.7	0.7	0.7	0.7	0.5	0.6	0.8	0.9	**0.398229**	0.7	0.7
CV len at age	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Sigma-R	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
# parameters	96	96	96	97	96	96	96	96	97	96	96

Table 4. Likelihoods reduced model (start 1964). Models that did not converge are recognized by (NC) below heading.

Likelihood component	base	*M*=0.2	*M*=0.4	*M*=est (NC)	*h*=0.5	*h*=0.6	*h*=0.8	*h*=0.9 (NC)	*h*=est	Equib Catch 150,000	Equib Catch 38000
Area1DWLL len	2613.45	2611.55	2619.32	2634.38	2612.5	2612.74	2614.51	2632.63	2633.63	2613.52	2613.42
Area2DWLL len	1764.53	1767.48	1761.61	1769.15	1763.66	1764.05	1765.1	1761.63	1766.59	1764.55	1764.52
Area3DWLL len	1395.49	1406.54	1387.46	1379.98	1394.72	1395.64	1394.76	1358.91	1377.84	1395.48	1395.49
Area4DWLL len	1443.98	1450.84	1436.18	1411.79	1442.33	1443.84	1443.34	1399.1	1408.14	1444.07	1443.94
Area5DWLL len	1376.5	1369.65	1382.54	1358.54	1377.21	1376.75	1376.31	1369.93	1363.17	1376.54	1376.48
Area1Train len	857.74	857.673	858.476	865.248	857.591	857.632	857.891	862.156	865.16	857.751	857.736
Area2Train len	1447.78	1454.45	1442.99	1449.47	1447.62	1447.73	1447.8	1445.88	1447.8	1447.8	1447.78
Area3Train len	2200.64	2204.44	2202.81	2227.93	2200.64	2200.33	2201.44	2227.2	2228.3	2200.6	2200.67
Area4Train len	4091.4	4123.43	4071.94	4113.97	4091.04	4091.21	4091.63	4131.63	4109.92	4091.42	4091.4
Area5Train len	494.259	492.811	497.261	497.18	495.541	494.688	494.093	497.579	498.96	494.17	494.308
Area1dtn len	733.283	735.412	730.748	737.291	732.947	733.244	733.167	728.04	736.768	733.323	733.266
Area3hwnll len	540.651	532.662	549.404	535.788	540.23	540.621	540.503	529.071	536.687	540.673	540.64
Area4hwnll len	385.039	383.106	388.19	384.874	384.927	385.081	384.888	379.931	385.163	385.048	385.035
Area5EPO len	1119.59	1144.61	1108.18	1266.42	1121.19	1119.81	1119.9	1150.71	1266.15	1119.51	1119.63
DWLL CPUE	-12.2042	-23.6913	-2.92999	-12.7095	-14.8208	-13.7763	-10.7895	-9.83166	-12.6507	-11.7022	-12.4342
HWN LL CPUE	-9.82726	-9.82714	-9.52523	-7.52565	-9.82673	-9.84429	-9.75897	-1.33741	-8.33587	-9.82697	-9.82715
CLL CPUE	-0.81421	-0.76586	-0.91543	-0.99420	-0.70992	-0.74811	-0.8914	0.32336	-1.06691	-0.81745	-0.8132
total	20434.2	20486	20424.5	20612.3	20423	20428	20440.6	20457.2	20594.8	20435.2	20433.8

Table 5. Key Parameters and Derived quantities Full Timeseries (start 1952). Non-converged models (NC) will not have estimated std. Estimated Parameter values are bolded.

	base	*M*=0.2	*M*=0.4	*M*=est (NC)	*h*=0.5	h=0.6	*h*=0.8	*h*=0.9 (NC)	*h*=est	Equib Catch 150,000	Equib Catch 38,000
B0 (t)	124739	195965	106456	129636	166726	140606	114968	8.59E+08	231928	125821	124291
B0 std	3.39E+03	5.94E+03	6.63E+03	5.65E+03	5.90E+03	4.10E+03	3.40E+03		4.28E+03	3.36E+03	3.41E+03
2005 6Spawn biomass (t)	10420	8432.52	15772.2	30455.1	9792.54	9841.77	11457.3	6.61E+08	29108.1	10434.9	10418.3
2005 Spawn Std	1.99E+03	1.50E+03	4.45E+03	4.61E+03	1.88E+03	1.86E+03	2.25E+03		3.68E+03	1.99E+03	1.99E+03
k	**229.151**	**221.903**	**236.206**	**198.089**	**228.751**	**229.138**	**228.966**	**225.25**	**198.182**	**229.178**	**229.14**
Lmax (EFL cm)	**0.135064**	**0.151492**	**0.120783**	**0.213432**	**0.135743**	**0.135097**	**0.135343**	**0.145163**	**0.212714**	**0.135032**	**0.135077**
M	0.3	0.2	0.4	**0.273771**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
h	0.7	0.7	0.7	0.7	0.5	0.6	0.8	0.9	**0.272357**	0.7	0.7
CV len at age	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Sigma-R	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
# parameters	92	92	92	93	92	92	92	92	93	92	92