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AN AGE-, SEX- AND SPATIALLY-STRUCTURED STOCK ASSESSMENT OF THE INDIAN OCEAN SWORDFISH FISHERY 1950-2012, USING STOCK SYNTHESIS

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Summary

An Indian Ocean swordfish (*Xiphias gladius*) stock assessment using *Stock Synthesis 3* (SS3) software is described. The approach uses a highly disaggregated model to integrate several sources of fisheries data and biological research into a unified framework. The model used is updated from the analysis conducted in 2011. Rather than use a fairly complex grid as used in 2011, the model examined this year key uncertainties, namely growth, natural mortality, steepness and weighting of the length composition data as opposed to the CPUE survey data (2 growth curves with 2 natural mortality vectors that correspond to the growth curves from a biological basis (total of 2 choices), 3 steepness values, and two weighting alternatives of data, and examining once CPUE series scenario that is equally weighted across all series, and one that only examines the Japanese CPUE series, with the EU fleets representing the SW Region). The implications of 10 years of projections over a ranged of constant catch levels (60, 80, 100, 120, 140% of current) are summarized in a management decision table (Kobe 2 Strategy Matrix), based on a weighted average of the model results. The analysis is conducted for the Indian Ocean stock as a whole.

Core assumptions in the aggregate Indian Ocean analysis included:

- The population is age- and sex-structured (dimorphic growth), iterated on an annual time-step from 1952-2012 (with constant catch projections to 2022) and spatially disaggregated into 4 areas. It was assumed that there is a shared spawning stock, but fish are only vulnerable to harvesting in the area of recruitment, (i.e. this might be described as foraging grounds site fidelity, such that the model can describe differential depletion and recruitment by area, but movement between areas was not estimated)
- There are 12 fisheries, each assigned to a single area and one of two (pseudo-) length-based selectivity functions: i) longline and ii) gillnet/other. The 'double normal' selectivity function was assumed for both, with flexibility to estimate either a dome or approximately logistic shape.
- Total recruitment follows a Beverton-Holt relationship, with annual log-normal deviates (in most models) and temporal variability in the proportional distribution of recruits among regions.
- The objective function includes lognormal observation errors on 10 CPUE-based relative abundance indices (4 Japanese by area, 4 Taiwanese by area, Portugal and Spain in the SW region), robustified multinomial terms for length composition data (8 fleets), lognormal recruitment deviations, plus a very diffuse prior for each of the estimated parameters.
- Estimated parameters included virgin recruitment, selectivity functions, recruitment deviations, catchability coefficients, and the spatial pattern of recruitment.
- Fixed parameters included: stock recruit steepness, variances on recruitment and CPUE errors, life history parameters describing growth, M, maturity schedule. While these values were fixed for each individual model, alternative combinations of fixed parameters were examined as described below.

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There are a large number of uncertainties in this fishery, and we attempted to quantify the implications of i) key assumptions that are difficult to justify, ii) parameters that are difficult to estimate, and iii) interactions among them in various permutations. In total, 24 models are discussed for the IO assessment following assumption:

- Growth rates, M and maturity:
    - Intermediate growth, M, and maturity (Taiwanese study in the Indian Ocean Wang et. al. 2010)
    - Slow growth, low M, late maturity (Australian study in the Indian Ocean Young et. al. 2010)
- Stock recruit steepness: h=0.6, 0.75, 0.9,
- Effective sample sizes for size composition data: 100% and 10% of observed, with maximum sample size capped at: 200, and 20, respectively.
- Relative weighting of the different CPUE series:
    - All series weighted equally,
    - Only using the Japanese CPUE series.

Results indicate that the stock is **not overfished**, and **not subject to overfishing**. Key indicators on the Indian Ocean Swordfish stock using a set of model evaluated across two growth curves and a range of Maturations, M's and effective sample sizes are shown below (ranges are plausible ranges across all models examined in Tables 7 and 8, and points are medians across all runs examined).

Management Quantity	IO - Aggregate Indian Ocean
Most recent catch estimate	26,016
Mean catch over last 5 years	24,579
MSY (t)	27.1K (16.8 K-112.5 K)
Current Data Period	1951-2012
F(Current)/F(MSY)	0.46 (0.09-0.96)
B(Current)/B(MSY)	
SB(Current)/SB(MSY)	2.46 (1.17-6.96)
B(Current)/B(0)	
SB(Current)/SB(0)	0.52 (0.3-0.87)

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Introduction

Swordfish (*Xiphias gladius*) are a large pelagic species, broadly distributed throughout the Indian Ocean to a southern limit of ~50° S. Indian Ocean swordfish have been taken by the Japanese longline fleet primarily as by-catch, since the early 1950s (Figure 1). The population was not heavily exploited before targeted fisheries began in the early 1990s. At this time the Taiwanese longliners began taking large numbers, initially in the SW region, followed by the other regions (Figures 1 and 3). The European longline fleet (predominantly Spain) started a targeted fishery in the 1990s, while only small numbers are reported in the driftnet fisheries, and purse seine catches are very rare. Total catches have declined substantially over the past few years (generally attributed to large effort decreases in the longline fleets due to piracy).

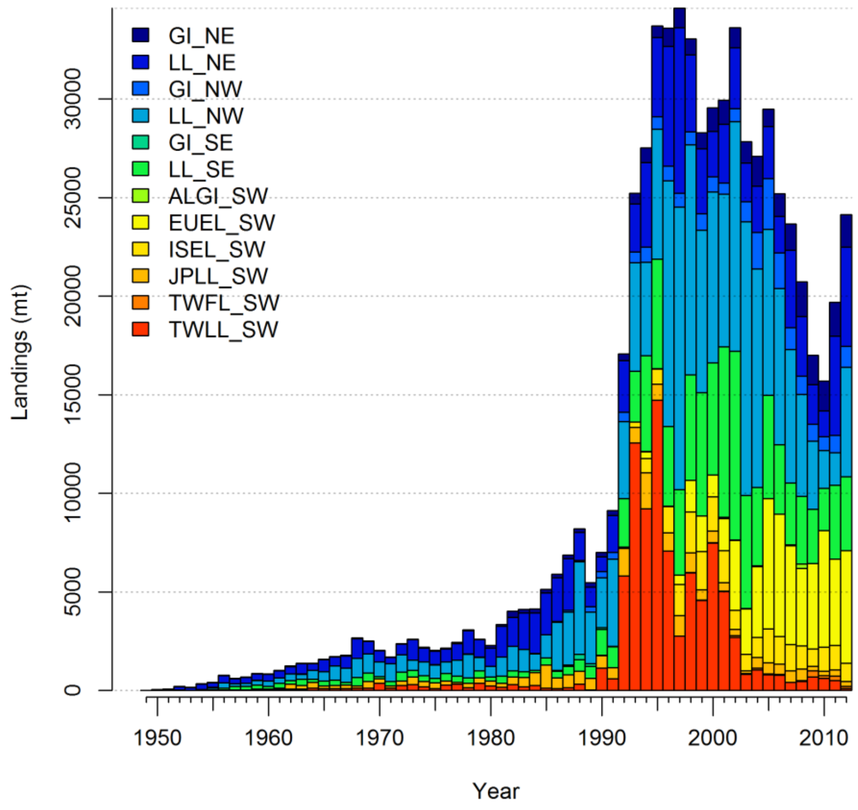


Figure 1. Total swordfish catch in mass by fishery over time for the whole Indian Ocean

In 2011, results from a range of swordfish (*Xiphias gladius*) assessments concluded that the Indian Ocean population as a whole was probably not overfished, nor experiencing overfishing (WPB 2011). This was a robust conclusion among the range of models from simple production models to highly disaggregated integrated models. However, the first attempt to explicitly quantify the south-west (SW) sub-population (under the assumption that it may represent a discrete population) indicated that it was probably highly depleted (Martell 2010). Immediately subsequent to the WPB, Kolody (2010) conducted a similar, but extended, analysis to explore the implications of several key uncertainties in the SW region, and demonstrated that there are plausible interpretations of the data that are much more optimistic. At the Commission meeting in 2011, the EU proposed a Conservation and Management Measure aimed at reducing fishing pressure on SW Indian Ocean swordfish. The CMM was not accepted, but the Commission report notes the following:

> *"The Commission **requests** that the Scientific Committee provide clear advice outlining alternative management approaches which would provide effective protection of a possible southwest Indian Ocean swordfish stock."* (IOTC 2011).

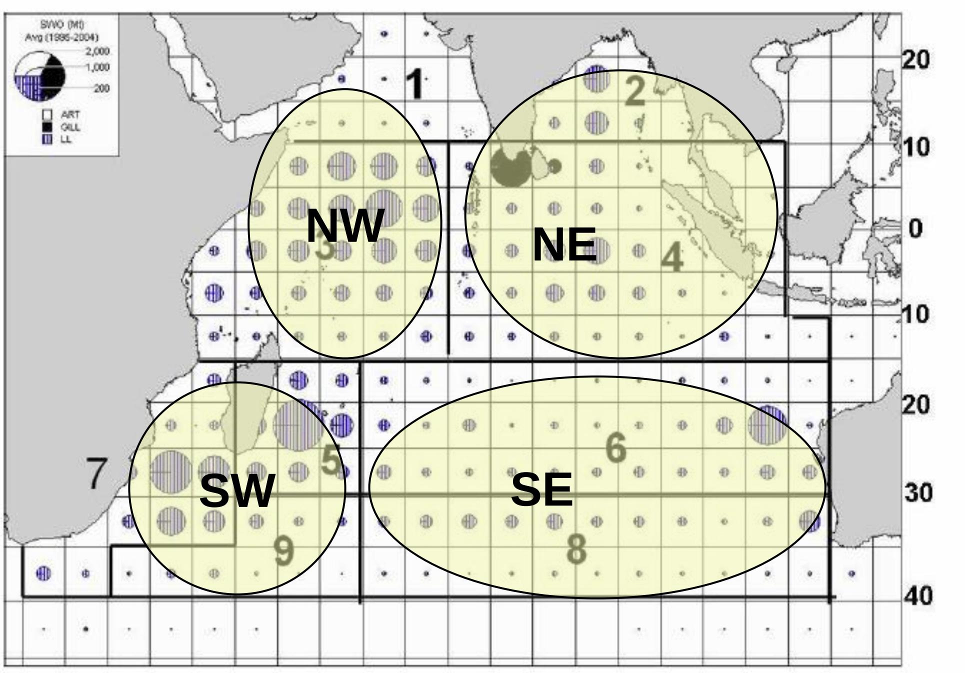


Figure 2. Spatial structure showing the 4 areas used in the model, superimposed on the IOTC statistical areas, and the swordfish catch distribution aggregated over 1995-2004.

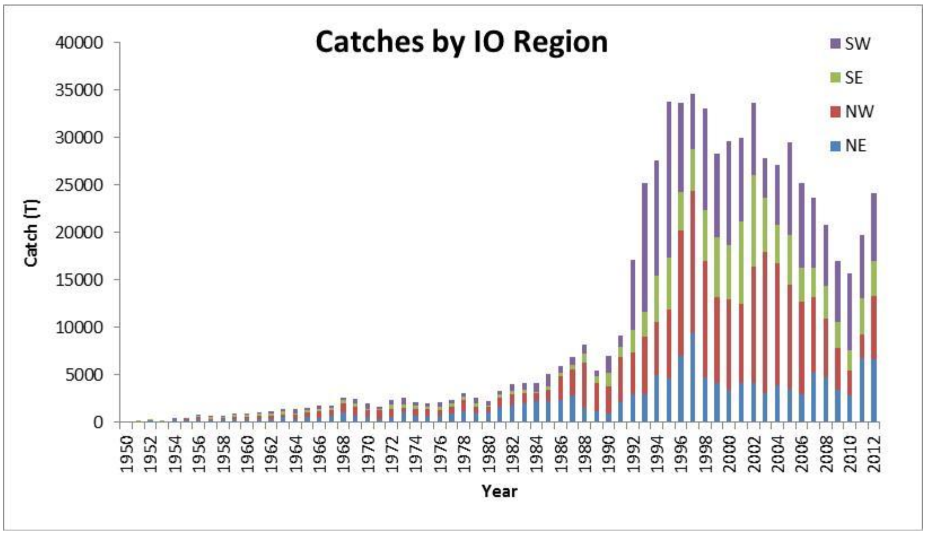


Figure 3. Total swordfish catch in mass by year and area (1950-2012).

The analysis in 2014 focuses on some key model formulations conducted in 2011 more extensively. Rather than look at a whole suite of models (243 models in 2011, Kolody and Herrera 2011), this approach focuses on 24 key model structures that examine growth, natural mortality, steepness, and weighting of CPUE versus length composition data, as well as look at formulations that fitted only to particular CPUE series available. The model incorporates the following:

- Three additional year of data,
- Improved over the period nominal catches and catch and effort data from IOTC database
- Revised CPUE time series for the Japanese and Taiwanese fleets,
- 24 fleets were aggregated into 12, and the model was iterated annually rather than quarterly (to increase computation speed)
- In the full Indian Ocean model, there was variability in the spatial distribution of recruits.

Management options are presented in the form of probabilistic outcomes from a range of constant catch projections (Kobe 2 Strategy Matrix decision table).

Methods

Data

There are many different fleets catching swordfish in the Indian Ocean, with vastly different gear types and levels of data quality (Herrera et. al. 2014). The fleet disaggregation is described in Herrera et. al. 2014.The 2011 SS3 assessment used only 12 fleets. There is enough uncertainty about the stationary selectivity assumptions, and the poor size composition data, that we would not expect the size composition data to be very informative about year-class strength.

Table 1. Fishery definitions for the Indian Ocean Assessment. Suffixes denote regions within the Indian Ocean as indicated in Figure 1: NW – North-West; NE – North-East; SW – South-West; SE – South-East.

Name	number	Area	Description
GI_NE	1	NE	Northeast Gillnet and other non-longline/-handline gears
LL_NE	2	NE	Northeast all longline and handline gears
GI_NW	3	NW	Northwest Gillnet and other non-longline/-handline gears
LL_NW	4	NW	Northwest all longline and handline gears
GI_SE	5	SE	Southeast Gillnet and other non-longline/-handline gears
LL_SE	6	SE	Southeast all longline and handline gears
ALGI_SW	7	SW	Southwest Gillnet and other non-longline/-handline gears
EUEL_SW	8	SW	Southwest European and assimilated longliners (target SWO)
ISEL_SW	9	SW	Southwest semi-industrial longliners (target SWO)
JPLL_SW	10	SW	Southwest Japan and assimilated longliners (target tunas)
TWFL_SW	11	SW	Southwest fresh-tuna longliners (target tunas)
TWLL_SW	12	SW	Southwest Taiwan,China and

			assimilated longliners and handlines (mixed target)
UJPLL_NW	13	NW	JPN CPUE series (1980-2012)
UJPLL_NE	14	NE	JPN CPUE series (1980-2012)
UJPLL_SW	15	SW	JPN CPUE series (*1980-2012)
UJPLL_SE	16	SE	JPN CPUE series (1980-2012)
UTWLL_NW	17	NW	TWN CPUE series (1980-2012)
UTWLL_NE	18	NE	TWN CPUE series (1980-2012)
UTWLL_SW	19	SW	TWN CPUE series (1980-2012)
UTWLL_SE	20	SE	TWN CPUE series (1980-2012)
URELL_SW	21	SW	POR CPUE series (2000-2012)
UESPLL_SW	22	SW	ESP CPUE series (2001-2012)

Total catch

Catch by year, fishery and area are shown in Figure 1 (from IOTC data file: SWO_SA_2014_samples.xls). It is assumed that the catch in mass figures provided by the CPCs are the most reliable catch data available. While the total catch data are not perfect, they are derived primarily from the industrial fleets in the Indian Ocean and are thought to be more reasonable than for the other billfish species.

Potential concerns were identified with respect to the catch time series:

- There appear to be substantial inconsistencies between the logbook data, the size composition data and the reported total catches for the Japanese and Taiwanese fleets (discussed under size composition below).
- The effects of discarding and depredation are not included in the catch statistics, and it is estimated that this may account for 30% of the Reunion catch covered by observers (it was unclear whether the units were mass or numbers, P. Bach, IRD, Reunion, pers. comm.).

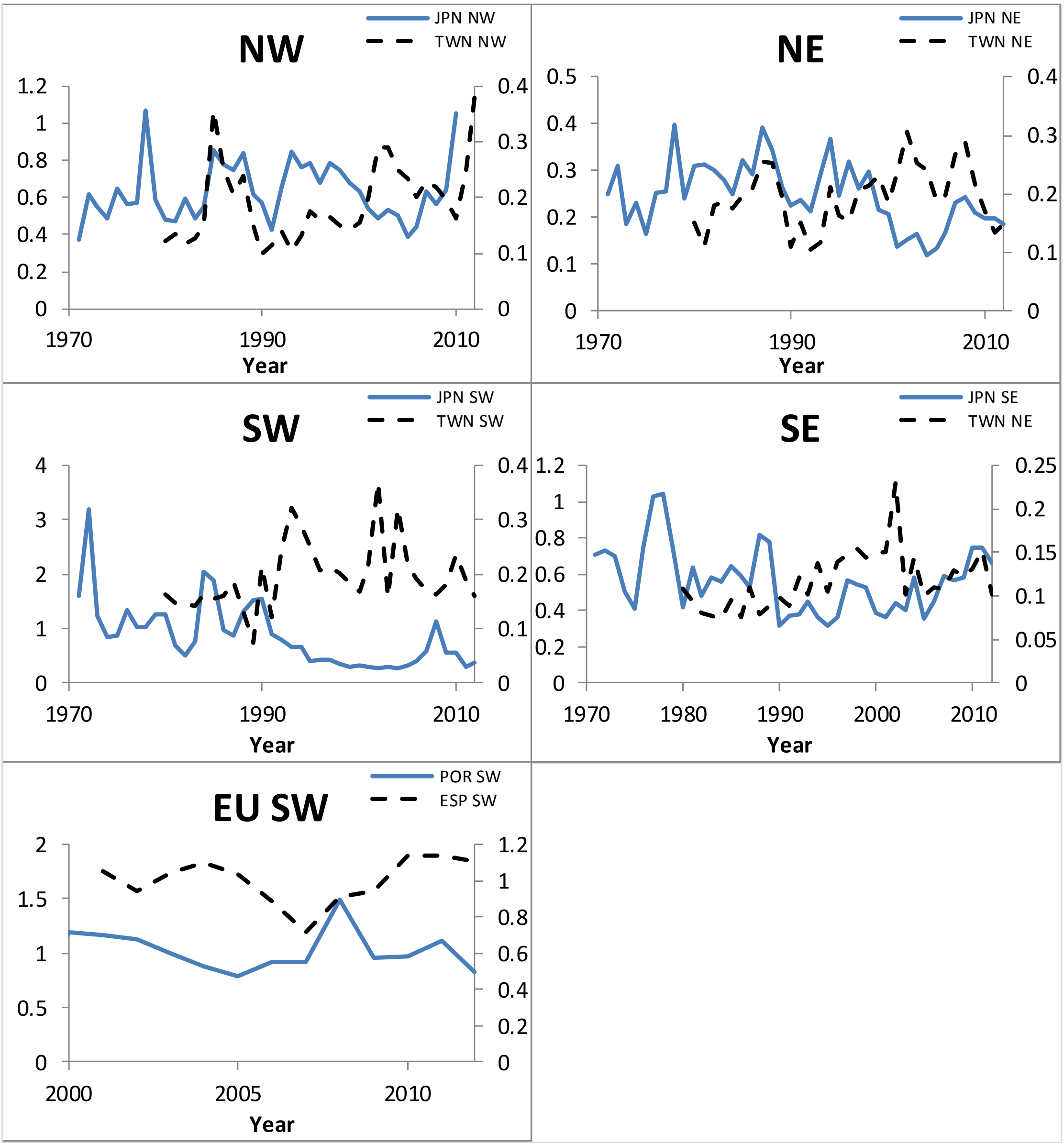


Figure 4. Standardized CPUE by area for Japanese, Taiwanese, Portuguese and Spanish longline fleets by sub-region based on papers submitted to WPB2012. All series have been rescaled so that they are visually comparable for relevant periods of overlap. Note that this re-scaling does not reflect the relative weighting across areas that is applied to the Japanese fleet.

Relative abundance indices

The standardized CPUE series in 2014 were somewhat different from those estimated in 2011 (Figure 4):

- The Japanese CPUE series were used for the period 1971-2012. The Taiwanese series is shorter 1980-2012, including only the period in which the Hooks Between Floats information is available (as a possible proxy for set-depth/species targeting).

  - Clustering approaches were used for the Japanese and Taiwanese fleets in 2014 (Nishida et al. 2014, Wang and Nishida 2014). The standardization in 2014 included fixed spatial factors (5° latitude and longitude bands) which should account for some of the concerns related to shifting spatial distributions of effort among years, and also account for targeting effects.

- Other fleets used were the EU Spanish and Portuguese fleets Santos et al 2014, Spanish reference 2014). The Reunion dataset was not used in 2014 .

- In most areas, the Japanese and Taiwanese standardized CPUE series are very noisy, on a time-scale that is not consistent with swordfish population dynamics. This unexplained variance may represent random noise, but it could be masking important changes to the fishery that bias the abundance estimates.

- In most areas, the CPUE series from different fleets appear to conflict to some degree, though some of this perception could be attributed to the over-interpretation of noise.

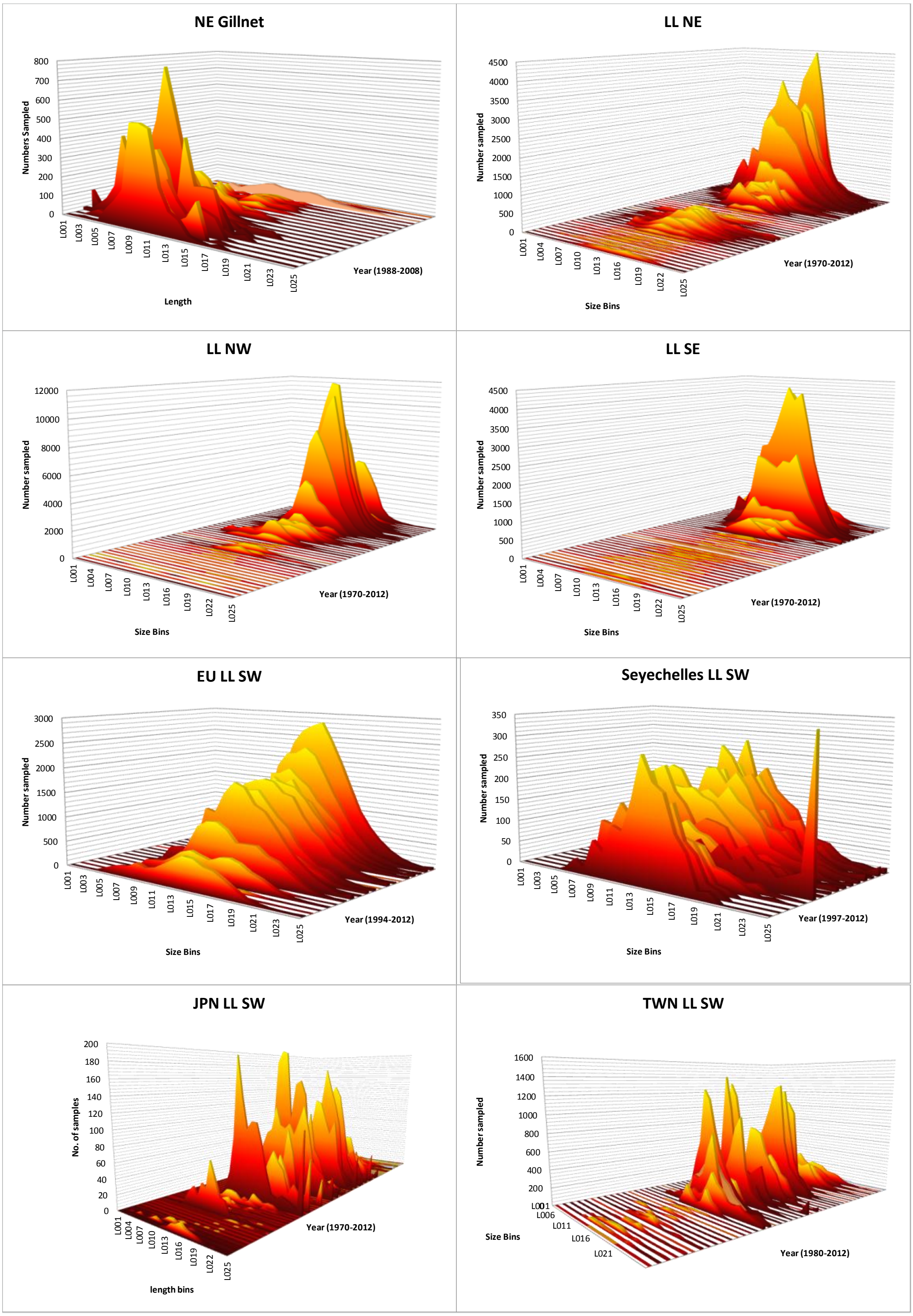


Figure 5. Swordfish size composition data by fleet over time Size was categorized into 25 9 cm increment bins between 45 cms and 252+ cms (the 1st bin is assumed to be between 15-45 cms).

Size composition data

Size data are available for 8 of the 12 fleets (from IOTC secretariat data file: SWO_SA_2014_SA.xls). Aggregated size distributions and time series of mean size are shown in Figure 5. Size composition data quality is often poor, with small and non-random sampling for many fleets, and changes in coverage over time (IOTC Secretariat 2014). The size data from Japan and Taiwan were historically provided to the secretariat at a very coarse resolution of 10° lat X 20° lon, but this has changed to 5° X 5° in recent years. This creates an additional problem in that the secretariat has to artificially partition these observations to fit the WPB spatial structure. There is also a pooling of data from different fleets, and it is noted that most of the Japanese size composition data is derived from the 'school' fleets, while most of the catch is derived from the commercial fleet, and the two fleets operate in different regions.

In 2009 and 2010, attempts were made to examine the size composition trends of the different fleets and entertain arguments about conflicting signals and different sources of data in relation to the plausibility of the data. In 2014 following 2012, the argument has been greatly simplified to the point that we are highly down weighting all of the size composition data for several reasons:

- Small sample sizes for many strata with non-random sampling. According to IOTC Secretariat (2014):
    - 1950-1969: The total catches of swordfish estimated for this period are low (below 1,500t in most years). No size frequency data are available for this period. The majority of the catches of swordfish for the period come from the Japanese and Taiwanese longline fleets.
    - 1970-1979: The total catches of swordfish estimated for this period range between 2,000t and 3,000t. Size frequency data is only available for the longline fishery of Japan. Between 3-16% of the total catches estimated (in number) are covered through sampling (i.e. 3-16% of the quarter x 10 x 20° strata includes some level of sampling). Samples are not available for the longline fishery of Taiwan,China during this period.
    - 1980-1991: The total catches of swordfish estimated for this period range from 2,000t to 8,000t. Samples are available for the majority of the strata having catches of swordfish, representing 55-90% of the total catches of swordfish estimated (in number), depending on the year.
    - 1992-2012: The total catches of swordfish estimated for this period range between 14,000t and 35,000t. Between 40-60% of the total catches estimated (in number) come from fisheries for which samples are available. The main problems are:
        - Poor sample sizes and time-area coverage for the longline fishery of Japan
        - Lack of length samples for the longline fisheries of India, Oman and various other flags (NEI)
        - Lack of samples or poor quality samples from gillnet and other artisanal fisheries.
- Discarding is likely, but poorly quantified:
    - Discards of swordfish are likely to occur in the driftnet fishery of Iran, as this species has no commercial value in this country (swordfish is forbidden by Islam in Iran as it has no scales).
    - Unreported discards also occur in LL fisheries, especially discards of small individuals (e.g. P.Bach, IRD, La Reunion, pers. comm.).
- There is evidence for spatial heterogeneity in size/sex composition in other oceans (e.g. larger, predominantly female fish are observed in the more southern latitudes of the South Pacific), but sex data are rare for the Indian Ocean
- Size trends differ among LL fleets in the same area. According to Herrera and Pierre (2014):
    - In recent years, the majority of the samples available from the longline fishery of Japan come from training vessels. The representativeness of the samples collected on training vessels is uncertain, as these vessels do not necessarily operate in the same areas or use the same fishing techniques as the commercial vessels from Japan (tend to catch larger swordfish).
- In 2011, there were inconsistencies among different reported sources of data (nominal catches reported in the landing statistics, logbook catch and effort data, and size

composition data), such that it is difficult to reconcile the total catches and the mean sizes reported. Figure 6 illustrates the time series of total catch (numbers) and mean length calculated when different sources of data are assumed to be reliable. For both the Japanese and Taiwanese fleets, there appear to be considerable discrepancies that merit further investigation.

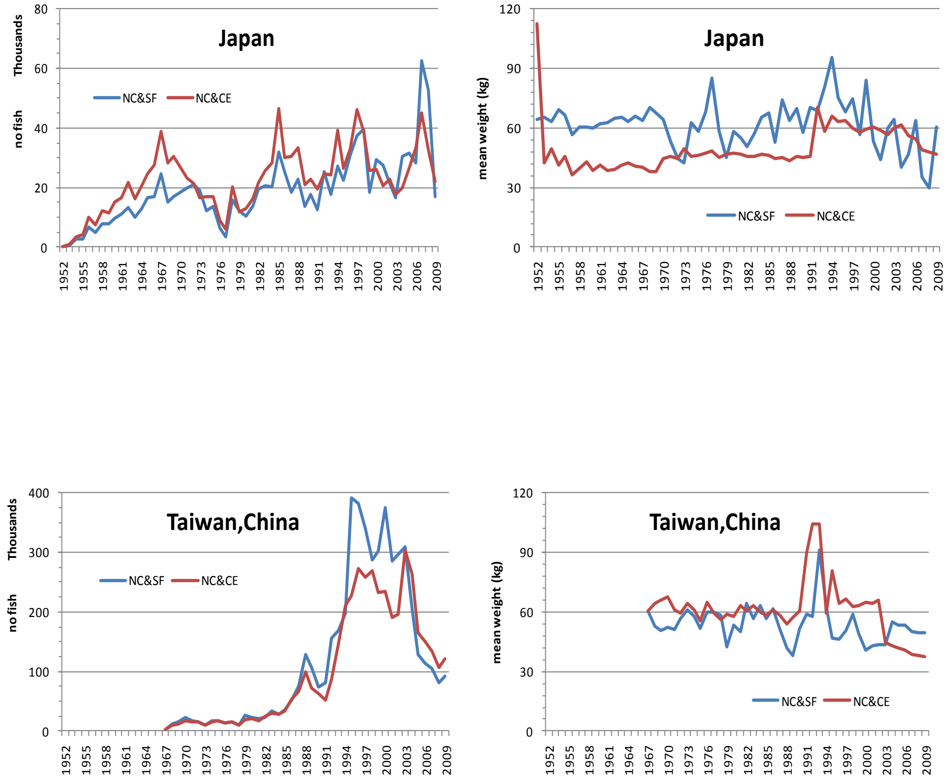


Figure 6 Potential conflicts among the total catch (NC), logbook (CE) and size frequency data (SF) for the Japanese (top) and Taiwanese (bottom) swordfish fleets. Depending on which data sources are used, the estimated numbers of fish caught (left panels) and the estimated mean size (right panels) can be very different.

Software

The analysis was undertaken with Stock synthesis SS V3.23d, 64 bit version (Methot 2000, 2009, executable available from http://nft.nefsc.noaa.gov/SS3.html), running on MS Windows™ 7. Typical function minimization of the fully disaggregated model on a 3.0 GHz personal computer required about 4 minutes. Additional simplifications and aggregations could probably reduce the minimization time further, without significant loss to the stock status inferences. However, given the current exploratory manner in which the model is being used to describe interactions among assumptions, the disaggregation is considered to be useful and the computation speed does not represent a real problem.

Model Assumptions

The most important model assumptions are described in the following sections. Standard population dynamics and statistical terms are described verbally, while equations can be found in Methot (2000, 2009). Attachment 1 is the template specification file for all of the models, and includes additional information on secondary elements of model formulation which may be omitted in the description below. All of the specification files are archived with the IOTC Secretariat.

Table 2 lists the assumption options that were combined in a balanced ‘grid’ design (i.e. all possible combinations of the listed assumption options were fit, while the other assumptions remained constant).

Table 2. Summary of SS3 specification options for the Indian Ocean assessment models. Other assumptions were constant for all models. The options below were applied in a balanced design (all possible combinations, such that a total of 3x2x2x2 = 24 models were fit for the IO).

Assumption	Option
Spatial domain	***io;*** Indian Ocean with 4 sub-regions
Beverton-Holt SR Steepness (h)	***h55;*** h=0.65 ***h75;*** h=0.75 ***h95;*** h=0.90
Growth, Natural Mortality and Maturity	***GtMf;*** Mixed Indian Ocean (Taiwan) ***GaMf;*** Eastern Indian Ocean (CSIRO)
CPUE* σ=SD lognormal errors	***A1;*** JPN σ=0.1; TWN σ=0.1; EU σ=0.1 ***NT;*** JPN σ=0.1; TWN σ=3.2; EU σ=0.1 (M values were asumed to 0.25 ot 0.4) in combination with the maturation and growth estimated from the Taiwanese and CSIRO models
Recruitment σ=SD(log(devs))	***R4;*** σ=0.4
Catch-at-Length (SS=assumed sample)	***CL200;*** *SS* = 200, lambda=1 ***CL020;*** *SS* = 200, lambda=0.1

**CPUE variances were adjusted using a weighting factor (λ) applied to the individual likelihood term, such that a lognormal likelihood with $\sigma_1 = 0.1$, combined with a down-weighting factor $\lambda = 0.001$ is equivalent to the original likelihood with $\sigma_2 = sqrt(\sigma_1^2/\lambda) = 3.16$. The error bars in the CPUE diagnostic plots are artificially narrow for the downweighted CPUE series (if plotted correctly the scale on these plots would be awkward).*

Time Period

The model was iterated from 1950-2012 using an annual time-step. There was no obvious loss of information in the change from quarterly (2010 assessment) to annual (2011 assessment) time-step; however, further analysis of seasonal processes is encouraged.

Spatial Structure and Migration Dynamics

A) Fast mixing –
single population model

B) Very slow mixing –
multiple separate population models
(SW model not examined here)

C) Shared spawning with
foraging grounds site fidelity
(IO model)

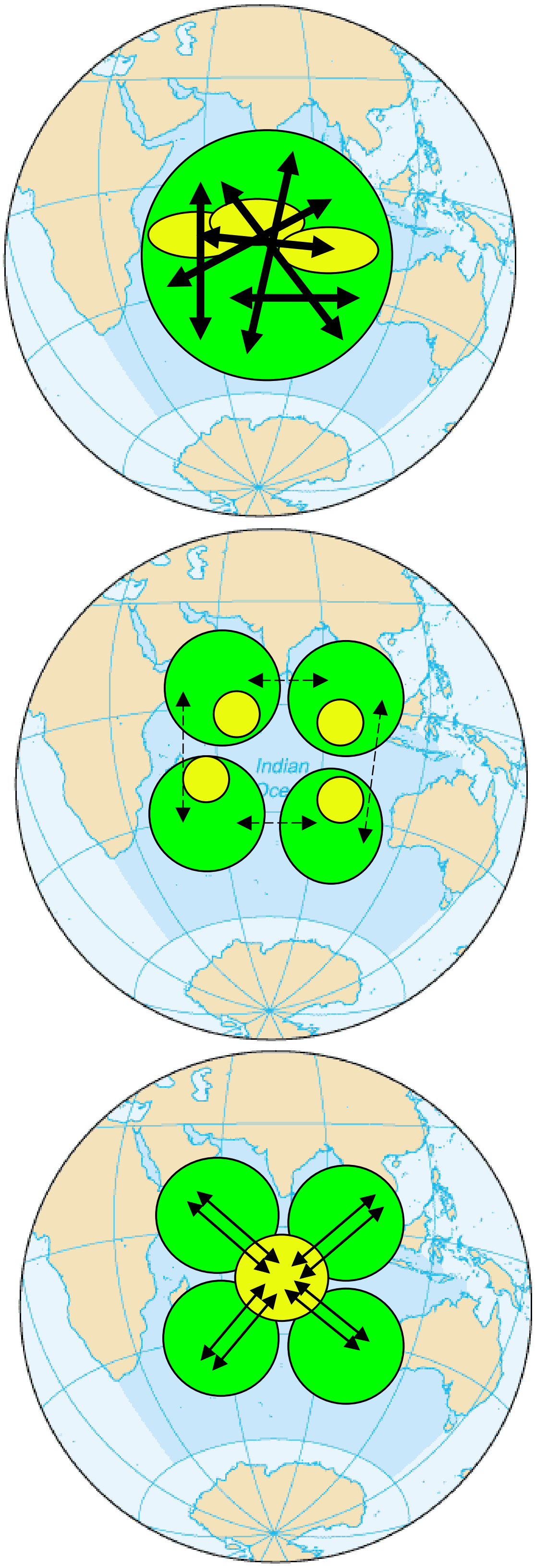


Figure 7. Cartoon of some alternative Indian Ocean swordfish population spatial hypotheses. Green circles represent foraging grounds, yellow circles represent spawning grounds, and arrows indicate movements to the larger green circles.

The appropriate spatial structure for the assessment remains uncertain. Different hypotheses have been proposed, e.g. Figure 7 summarizes the options that have been explored for IO swordfish to date. Others are also possible, e.g. discrete spawning populations with mixing in common foraging grounds (not shown). Some evidence suggests that there may be genetic distinction within the IO, and this was the subject of an investigation (IOSSS project led by IFREMER, Reunion (Bradman et al. 2010. Bourjea et al 2011). Based on results obtained in 2013 (WPB 2013, Muths 2013), there is no differences in genetic structure obtained from the SW Region and the entire IO Region (Muths et. al. 2013). As such, only one area assessment with movement across different quadrants (Figure 4) was examined.

Aggregate Indian Ocean Model (IO)

The model is disaggregated into 4 areas corresponding to those used in the JPN and TWN catch rate standardization analyses in recent years (Figure 4 and Figure 7). Given the vast size of the Indian Ocean, and the migration rate inferences that have been made from tagging studies to date, it seems unlikely that there would be rapid mixing processes across the whole basin, even if the population was genetically homogeneous (but we note that a few trans-Atlantic swordfish migrations have been recorded (Kadagi et al 2011)). As such, localized overfishing could result in negative local consequences even if the population is genetically homogenous. The 4 area structure is a pragmatic disaggregation that conveniently partitions most of the national fleets, and allows special treatment of the SW region.

There are very few direct observations of swordfish migration in the Indian Ocean. The few conventional tag recaptures and satellite GPS tag deployments near the Australian coast provided no indication of large scale movements (but these studies are limited by biased recovery effort and short deployment times respectively) (Karen Evans, CSIRO, Australia, pers. comm.). It is noted that the African Billfish Foundation probably has the largest swordfish tagging database in the Indian Ocean, and this should be considered in the future (Kadagi et al 2011). There is also a paper from Wendy WEST with 4 pop_ups tags (WPB in South Africa)

We can indirectly infer that there are probably some relatively large seasonal migrations. Swordfish can be caught at least as far south as 45° S, however, the spawning regions (and larval distributions) have all been identified in the tropical regions. In the southern hemisphere at least, this suggests substantial directed seasonal migrations. The spawning season also seems to be several months out of phase between the northern and southern regions. It is not clear whether this represents a single annual migration between north and south, or whether distinct populations independently move between lower and higher latitudes in each hemisphere. However, in many cases, resolving the directed seasonal migration patterns is not required in an assessment.

In principle, SS3 can be used to estimate movement rates among areas, however, these estimates are generally of little value in the absence of tagging data. In all of the models used in 2011, migration rates were fixed at very low levels (<< 1% per year), which essentially creates 4 populations except for the shared spawning and recruitment dynamics (foraging grounds site-fidelity).

Fishery Definitions

Twelve fisheries were defined, corresponding to the data aggregation units supplied by the IOTC Secretariat (Figure 1, Table 1). In 2014, fleets from different nations were pooled into either LL or Other. Assessments in 2009-10 did not indicate that much useful information could be extracted from the individual fleets and disaggregating the selectivity made little difference to the results.

Age Structure

The swordfish population was age-structured with cohorts of 0-30+ years (in unfished equilibrium, <0.25% of the population survives to reach the plus-group with the lowest M value considered).

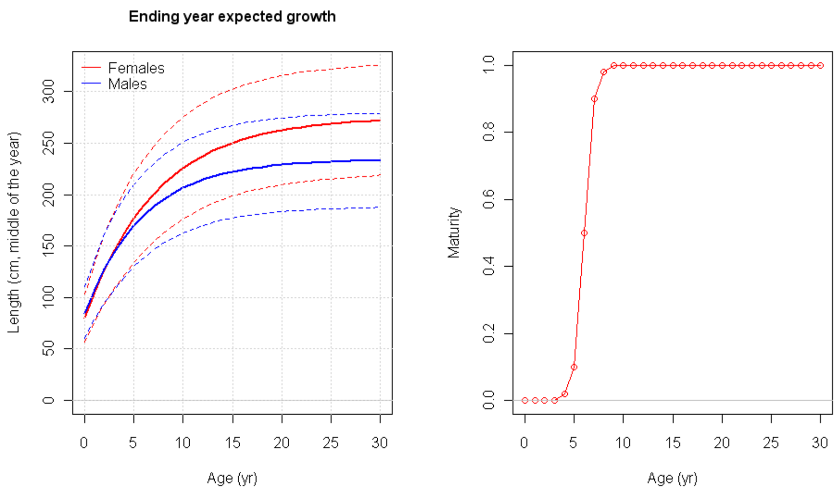
Sex Structure

The swordfish population is sex-structured to (potentially) account for a number of sex-specific population features that may be worth describing, notably:

- Growth curves differ by sex, and it is useful to be able to represent the two distributions (or aggregated of the two distributions) in the catch-at-length likelihoods (or it would be useful in principle, if we were confident about the growth curves, size composition data, mortality estimates and stationary selectivity assumptions)
- Spatial distributions often differ by sex (e.g. large females disproportionately found in cooler temperate waters in the south Pacific)
- Selectivity may differ by sex due to the differing spatial distributions, and there also may be direct size biases in some fisheries (e.g. commercial fishers report that large swordfish may be less vulnerable to circle hooks).
- Natural mortality may also be sex-specific, but no distinction was made in these models.

To date, there is no evidence that the sex structure is contributing much to the behaviour of the model in its current form, however, the computational overhead is maintained for future development.

Age and Size



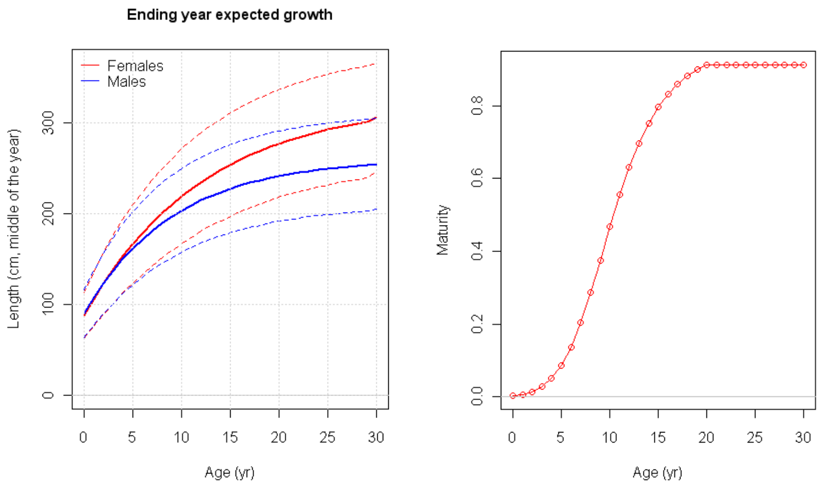


Figure 8. Growth (left) and maturity (right) for the 2 different options: Taiwan (GtMf, top) and CSIRO (GaMf, bottom).

There is strong evidence for sex dimorphism in swordfish, and this can potentially become important in the right-hand tail of the size distribution which is often estimated to consist predominantly of large mature females. Two alternative sets of growth curves were explored to admit the uncertainty due to potential area-specific growth rates, and ongoing concerns about methods of age estimation from fin spines (Figure 8):

- CSIRO estimates very slow growth based on South-East Indian Ocean fin rays samples (Young and Drake 2004).
- Wang et al. (2010) described an intermediate growth curve (pooled western and eastern samples from the Indian Ocean equatorial region).

Length-at-age was assumed to be normally distributed around the mean length-at-age relationship with a CV of 15% at age 0, decreasing linearly (in proportion to length) to 10% at age 30+.

Maturity and Spawning Stock Biomass

While a number of studies quantify the relationship between size and maturity (and there is some uncertainty here as well, also discussed in Young et al. 2008), the uncertainty of age estimation that undermines the growth relationships also undermines the maturity/fecundity by age relationship. Two relationships were assumed, one for each growth curve (Figure 8):

- 50% maturity ~age 10, corresponding to the CSIRO study (mostly based on SW Pacific samples, Young and Drake 2002).
- 50% maturity ~age 6, logistic function, applied to the Taiwanese growth.

Natural Mortality

The central value of M=0.25 (constant over ages) was adopted for the Taiwanese growth curve, to maintain consistency with Wang and Nishida (2010b). For evaluating how sensitive these runs are to Natural mortality a value of 0.4 was used as well to show extreme cases in sensitivity (NMFS study, Young et. al. 2008).

Selectivity

In 2009, results were found to be insensitive to selectivity assumptions (age-based vs: pseudo-length-based; 18 functions vs: 3 functions). In 2014 following 2011, only two different size-based “double normal” selectivity curves were estimated, one for longline fleets, and one for the gillnet (and other associated) fleets. The double normal selectivity has considerable freedom to represent a dome-shape, or an approximately logistic curve that either reaches a plateau or is monotonically-increasing.

Selectivity was parameterized as a pseudo-length-based function, i.e. the length-based curve is internally converted to an age-based function based on the length-at-age relationship. In this application, the potential benefit of this arises as a result of the sex dimorphism (i.e. two sex-specific age-based selectivity functions are derived from a single length-based selectivity function because of the difference in length-at-age). While the length-based selectivity function often exhibits a very steep ('knife-edge') slope, this is deceptive because there is considerable overlap in length-at-age, and selectivity is ultimately operating on ages.

CPUE and Catchability

The annual CPUE indices were assumed to be directly proportional to selected abundance mid-year (mass for the ESP fishery, numbers for all others). It was generally assumed that each informative CPUE series was highly (unrealistically) informative with observation errors SD(log) = 0.1. We do not really have this much confidence in any of the CPUE series, however, we have even less confidence in the size composition data and other structural assumptions. This assumption reflects the fact that an assessment might be useful without size data, but is generally meaningless without a relative abundance index (and similarly, it is probably meaningless if the model does not fit the abundance index to a sufficient degree).

When a particular CPUE series was assumed to be uninformative, it was heavily down-weighted (lambda = 0.001, or equivalently σ=3.2), but still included in the model, so that the fit of the series could be examined (even though the series has minimal influence on the parameter estimation).

Catchability was assumed to be constant over time for all CPUE series. An area-specific scaling was applied to the Japanese CPUE series to convert the density indices to relative abundance indices that are comparable among areas (i.e. CPUE = 1 in the NW region and CPUE =1 in the SW region implies that the two regions have identical abundance, not simply identical density). This allows catchability to be shared among areas for all of the Japanese fisheries. The shared catchability constraint is often useful for preventing bizarre localized behaviour in spatial models. However, the validity of the assumption that density is uniform within each large sub-region is questionable. Given the nature of the swordfish fishery, it may be unrealistic to expect that swordfish catchability in a northern bigeye fishery has much relation to swordfish catchability in a southern SBT fishery, and the implications of these types of assumptions warrant further investigation. Note that there is an equivalent assumption involved in creating a single abundance index for the whole Indian Ocean as applied in the spatially-aggregated models. .

Two different catchability assumptions were explored:

- A1: all CPUE series weighted equally in the likelihood (σ_{CPUE} = 0.1)
- J1: Japanese CPUE treated preferentially (σ = 0.1), others down-weighted (σ = 3.1)

In 2011, a catchability scenario was explored in which it was assumed that there was a fundamental shift in operations between 1990 and 1991. This was eventually discounted, but it still remains unclear whether something strange happened in the Japanese fleet in the SW during the early 1990s.

Fishing Mortality and Catch in mass observation errors

The model is conditioned on catch (mass), such that it is assumed to be known without error, and extracted perfectly. The SS3 "hybrid" fishing mortality parameterization was used, in which SS3 starts with Pope's approximation and then conducts a fixed number (4) of iterations to approximate instantaneous F from the Baranov catch equation.

Assumptions about the Catch-at-Size data

Size composition was partitioned into 24 bins of width 9 cm (except the first and last), from <45cm to >252 cm). Some of the swordfish sample sizes appear to be very large for some fleets. In the context of separable models (stationary selectivity), a literal interpretation of these very large sample sizes could be misleading in the assessment for a number of reasons, including: i) sampling is probably not truly random, ii) selectivity is probably not stationary (e.g. the spatial distribution of many fleets change over time, and most fleets change targeting practices), and iii) there is considerable uncertainty in the length-at-age relationships and M. To partially account for these problems,

- Each length distribution with fewer than 10 fishes was discarded.
- The input sample sizes (i.e. assumed number of purely random samples in the likelihood terms) were capped at 20 or less (see below).
- A somewhat arbitrary proportion (0.01) was added to each of the predicted and observed length bins to reduce the influence of outliers.

The influence of the size composition samples on the model behaviour and stock status was examined with 2 options in the assessment grid:

- CL200, sample sizes were capped at 200
- CL002, sample sizes down-weighted by factor of 100, and capped at 2.

Stock Recruitment Relationship

A Beverton-Holt stock recruitment relationship was assumed with steepness fixed at a range of options. Spawning biomass was calculated as the mass of mature females. In the spatially disaggregated model, this represents the sum across all regions. The three steepness options below reflect the fact that steepness is notoriously difficult to estimate, and forcing a range of options probably results in a more realistic representation of the real uncertainty:

- h60: steepness (h=0.6)
- h75: steepness (h=0.75)
- h90: steepness (h=0.9)

Recruitment was assumed to occur annually (quarter 1). There is anecdotal evidence to suggest that spawning (and recruitment) may be out of phase in the southern and northern hemispheres, however the growth, size sampling and selectivity assumptions are such that the quarterly model explored in 2009-10 could not provide much insight into recruitment processes. Recruitment variability was fixed at σ_R = 0.4. Recruitment deviates were estimated from the 1950's to 2010. Note the first few years, the deviates were centered around 0 due to lack of infoamtion to estimate these paramters.

Recruits in the final two years were deterministic from the stock recruitment relationship, because these cohorts are only weakly observed by the data (and dev vectors constrained to a mean of 0 can take large liberties with unconstrained deviates). The lognormal bias correction term was applied only to the unconstrained recruitment deviates.

Initial Population

The population was assumed to be in unfished equilibrium in 1950, the start of the catch data series.

Model fitting

Parameters were estimated by minimizing the objective function consisting of the following terms:

Likelihoods:

- Relative abundance indices with lognormal observation errors (10 series for the aggregate IO model, 4 series for the SW sub-region models). Depending on the CPUE option, some of these CPUE series may have been down-weighted to the point that they were uninformative.
- Length frequencies – multinomial sampling assumptions (with assumed sample sizes << reported sample sizes, and a robustification term, the lambda multiplier)

Prior distributions and Penalties:

- Annual recruitment deviates (lognormal) from the stock-recruitment relationship.
- Every estimated parameter for selectivity, catchability, R0, and steepness (the latter in a few cases only), requires a prior probability distribution. For these parameters, the prior adopted was very diffuse, such that a bound was likely to be hit before the prior would exert an appreciable influence (e.g. SD = 99).
- Weak penalty (e.g. SD = 99) on the spatial distribution of the recruitment deviates in the 4 area model.
- Smooth penalties for parameters approaching bounds were adopted, however, bounds were not approached for any of the models discussed here (i.e. presumably because the most difficult to estimate parameters were generally fixed (i.e. growth, M, steepness).

The informative parameters estimated by the model included:

- Catchability for the informative CPUE series
- Selectivity parameters
- Virgin recruitment
- Annual recruitment deviations from the stock recruitment relationship
- Annual area-specific recruitment deviations (IO models only)
- Recruitment distribution by area (IO models only)

Note that SS3 lists additional parameters as being estimated, but should not have had any significant influence on the estimated dynamics (e.g. forecast recruitment deviates).

Uncertainty Quantification and Synthesis of Model Results

Initial runs were undertaken with updated CPUE data from TWN and EU Portugal. Walters and Hilborn (1992) suggest using only one series of CPUE as it represents a state of nature and one plausible hypothesis. Based on these we examined a run with Taiwanese CPUE data only, and a Japanese one only, as these are the primary sources of information in the Indian Ocean. However, it appeared that the Taiwanese data were non-informative (results not shown here), and we this chose to look at the options above (only Japan, and all series weighed equally).

The stock assessment process typically involves a search for one or a very few model specifications which appear to be plausibly consistent with the data, and a priori expectations. Most commonly, some form of statistical approach is used to describe uncertainty (*e.g.* likelihood profiles or Bayesian posteriors) for the quantities of interest, under the assumption that a particular model is 'correct'. The approach adopted here is similar to the approach used by the CCSBT (originally in the context of stock assessment, and subsequently in the development of operating models for Management Strategy Evaluation).

Rather than look at the whole suit of uncertainty from Kolody and Herrera's s assessment in 2011, we decided to examine the key pieces that had the largest influence on the likelihood, namely growth, natural mortality, and steepness. In addition, we discounted the length composition data (Francis 2011) as they have been inconsistent sampling of some of the fleets, and a large decline in samples from Japan on one hand, with a huge increase from TWN,China on the other hand (Figure 5). Each of the models examined here, could be a plausible model and the range of uncertainty is encapsulated by the 48 models here.

Projections and Kobe 2 Strategy Matrix

Projections were conducted from the MPD estimates of all models at catch levels of 60%, 80%, 100%, 120% and 140% of 2008 levels (assuming 2012 selectivity and catch allocations among fisheries). The projections used deterministic recruitment from the stock recruitment relationship (starting in 2010). This approach ignores two important sources of uncertainty: statistical uncertainty in the parameter estimates, and recruitment variability. However, as discussed in the previous section, the approach does incorporate the model selection uncertainty, which is usually greater than both of these sources of uncertainty in most cases. However, if the model selection process results in a very small subset of heavily weighted models, or important decision are required in relation to the tails of the distribution, the additional sources of uncertainty should be considered. Three and Ten year projection results are summarized in a management decision table (Kobe 2 Strategy Matrix), i.e. The projections are summarized in terms of a weighted average of results that describe the proportion of scenarios in which

- SPB(2015)<SPB(MSY), SPB(2022)<SPB(MSY)
- F(2015)>F(MSY), F(2022)>F(MSY)

Results and Discussion

The aggregate IO assessment are presented separately below.Given the large number and complexity of the models, it is not possible to show the detailed results for all of them. The approach used here is to provide detailed results and diagnostics for a typical model, summary quality of fit indices for all models, and subsets of results that emphasize the main points of interest. The files are archived with the IOTC Secretariat.

Aggregate Indian Ocean Assessment

On the basis of the maximum gradients, none of the models indicated a gross minimization failure, though a few models might be considered marginal.

Base Case Model Examined

All CPUE indices were used, and effective sample sizes for age structured data were kept at 2 (low effective sample sizes). Steepness was kept (0.75) in the middle range and CSIRO growth model was examined and how it performed. Males and females grow at slightly different rates and the effect on overall biomass and yield estimates is shown in figures showing the main fits, and areas (note all runs here use Japan, Taiwan, EU Portugal). However, when used this model gave very poor fit to the CPUE data on all fleets, and gave unrealistically high values of R0 leading to very high B0 levels. In order to capture the trends of the Japanese CPUE in the 1970's as well this model did not perform well and had to compensate for very high CPUE's observed in early 1970's. The fit to the latter half of the Japanese series is also poor (Figure 9). Thus this model was discounted.

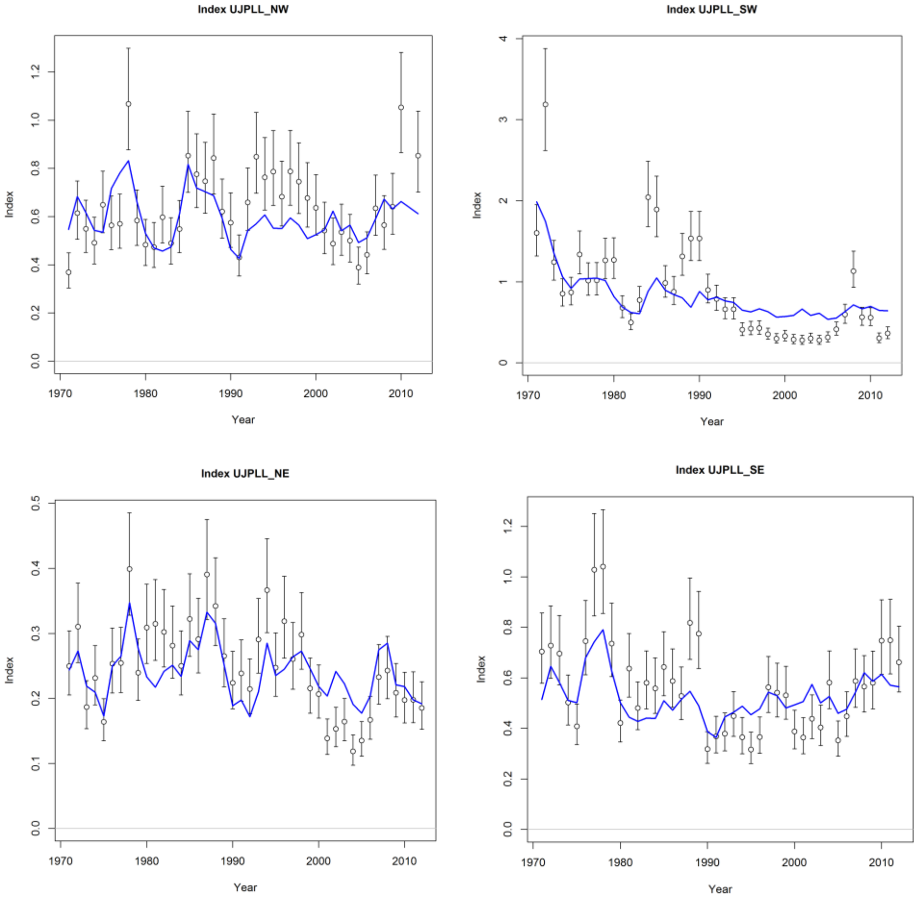


Figure 9: Poor fits to Japanese CPUE. The fit was poorer for TWN, China (not shown here)

We thus truncated the Japanese series to 1981 onwards (same as the Taiwanese series). and we decided to fit the model weighing the Japanese CPUE data by 2, compared to the Taiwanese CPUE and by 4 compared to the European CPUE. The Biomass trends appeared to be more realistic as compared to the R0 and B0 values obtained from the previous run (Figure 10) , and we compared these fits to equal weighted series for Japan, Taiwan and the EU (Figure 11, 12& 13). The model dynamics are quite similar so, we chose to only evaluate the case of equal fits in subsequent cases as shown in Table 2.

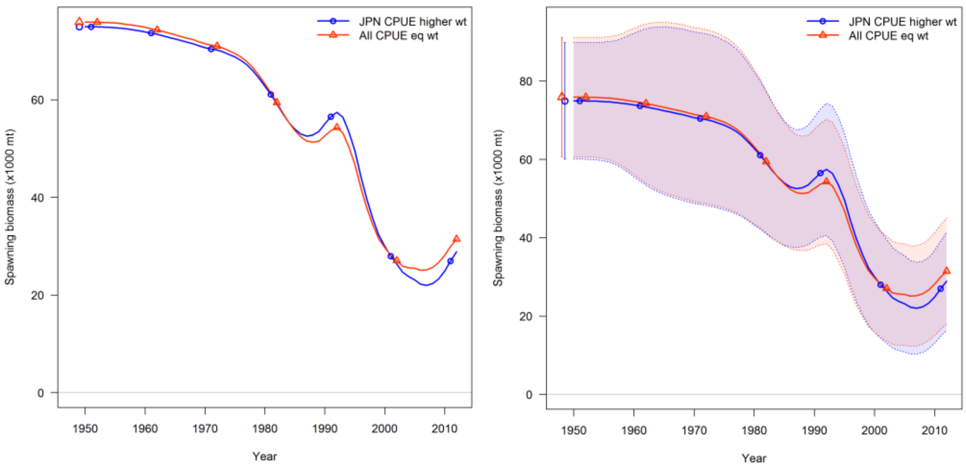


Figure 10: Spawning Biomass Trajectories using equal weights or higher weights on the Japanese series from 1981 onwards.

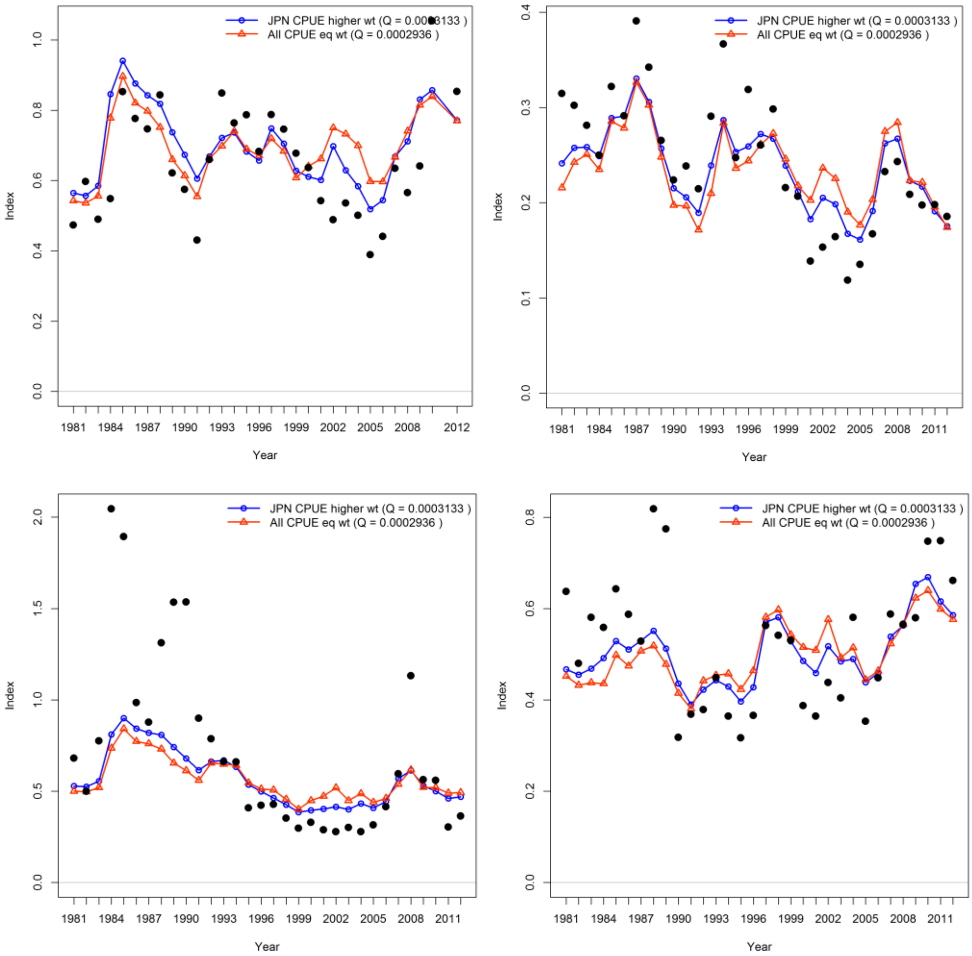


Figure 11: Observed versus predicted fits for the Japanese CPUE series (upper left quadrant is NW, upper right is NE, lower left is SW, and lower right is SE).

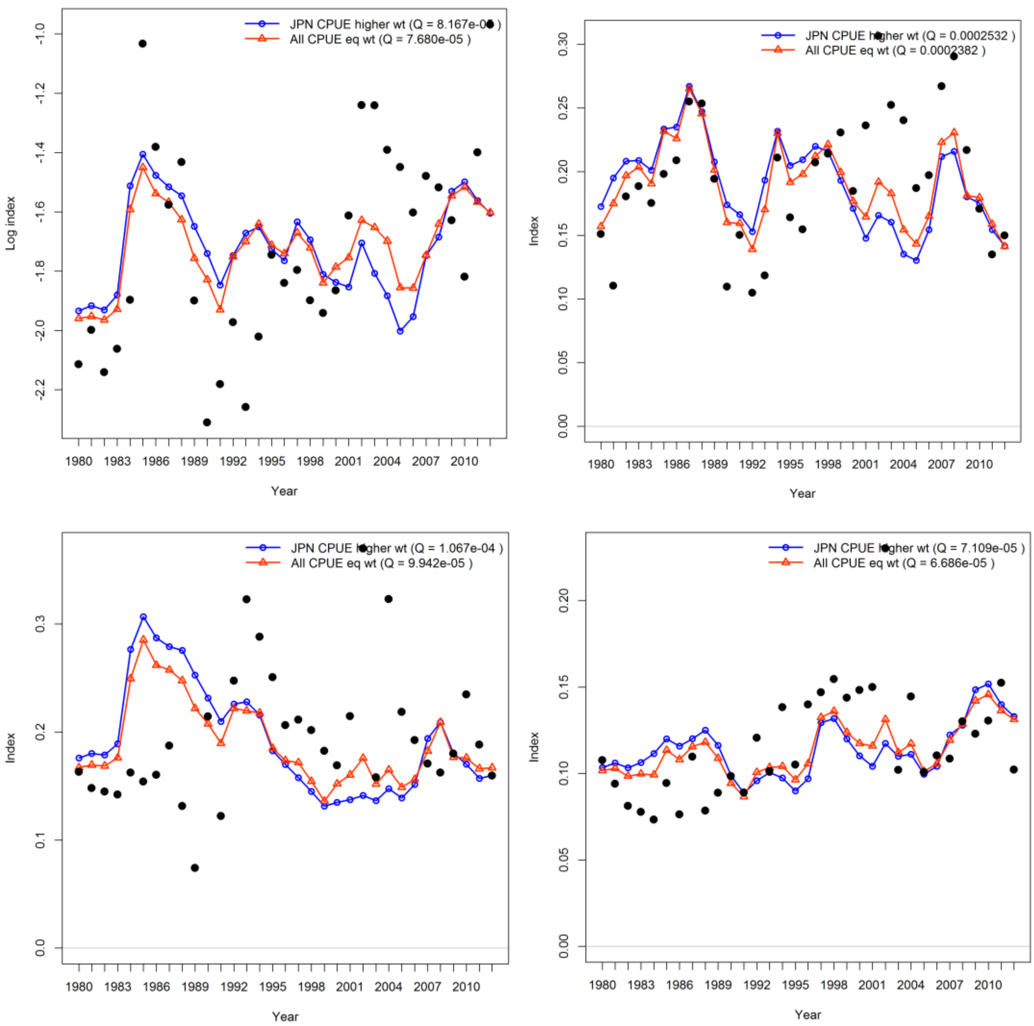


Figure 12: Observed versus predicted fits for the Taiwanese CPUE series (upper left quadrant is NW, upper right is NE, lower left is SW, and lower right is SE).

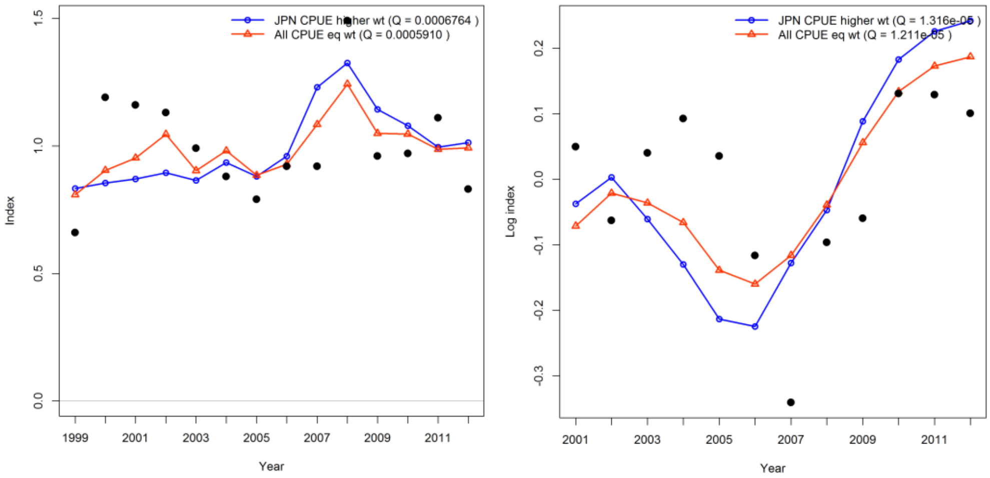


Figure 13: Observed versus predicted fits for the EU CPUE series (left quadrant is Portugal, and the right is Spain).

We now refined the grid (Table 2) to a new setup as the original structure was modified, based on the CPUE series examined.

Refined Base Case

We used the model described above with the CSIRO growth pattern, steepness (h=0.75), the low effective sample size on the length composition data, and all the CPUE data weighted equally from 1981 onwards as the **Base Case.**

Fits to the age composition across fleets was poor (Figure 14), and even worse across time (not shown). Selectivity appears to be fully selected by 100 cms with a small decline at around 175 cms in most fisheries (Figure 15). Fishing mortality rates seems to rise significantly in the late 90's and early 2000's with a drop after the advent of pairacy (Figure 16) and spawning Biomass across regions (Figure 17) shows a steady decline (other than region 3, the southwest) though seems to steady over time for this stock. Finally the stock trajectory using a phase plot is shown for this run (Figure 18), and key elements of the base run in terms of reference points are shown in Table 3.

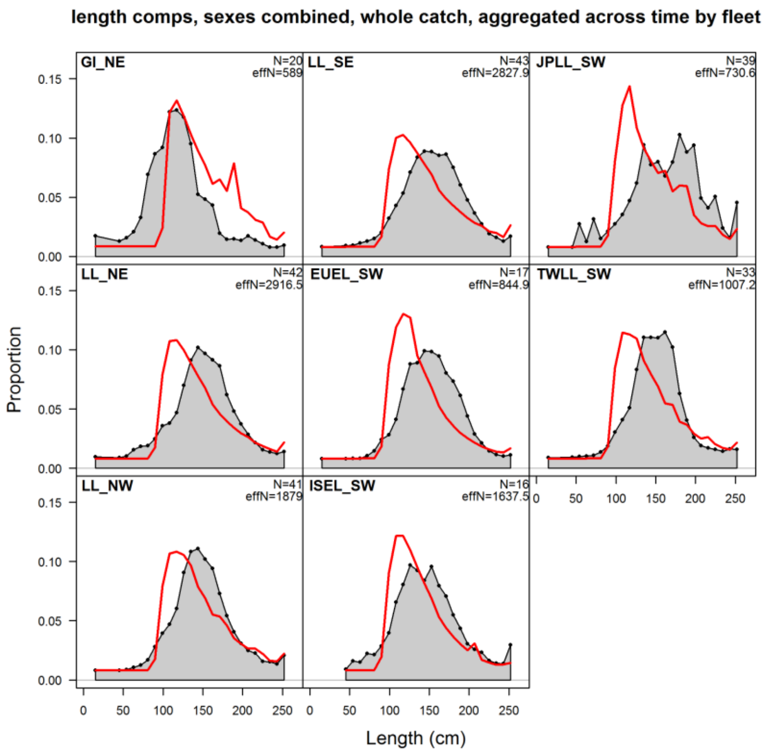


Figure 14: Fit across size classes

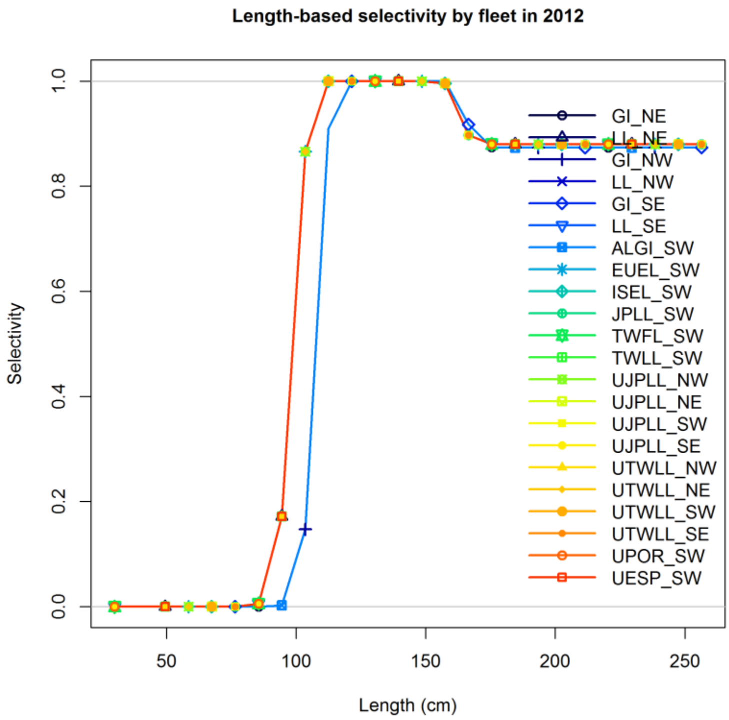


Figure 15: Selectivity by fleet and time

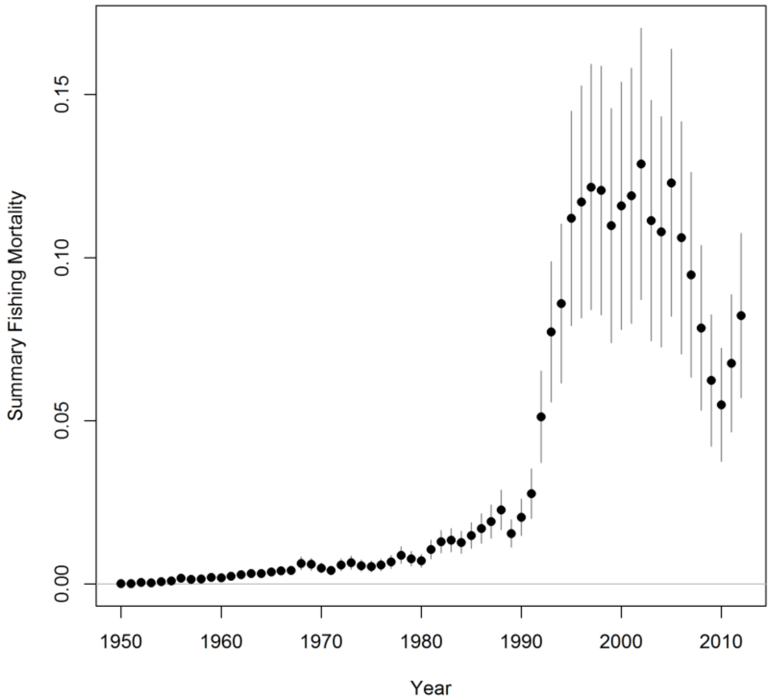


Figure 16: Fishing Mortality over time

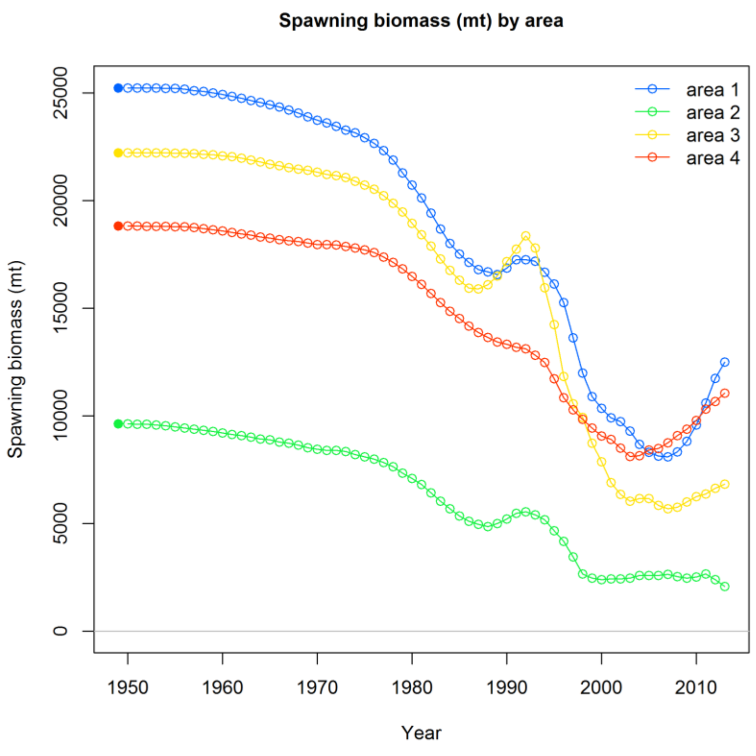


Figure 17: Spawning Biomass by Areas (area 1 NW, area 2 NE, area 3 SW, and area 4 SE)

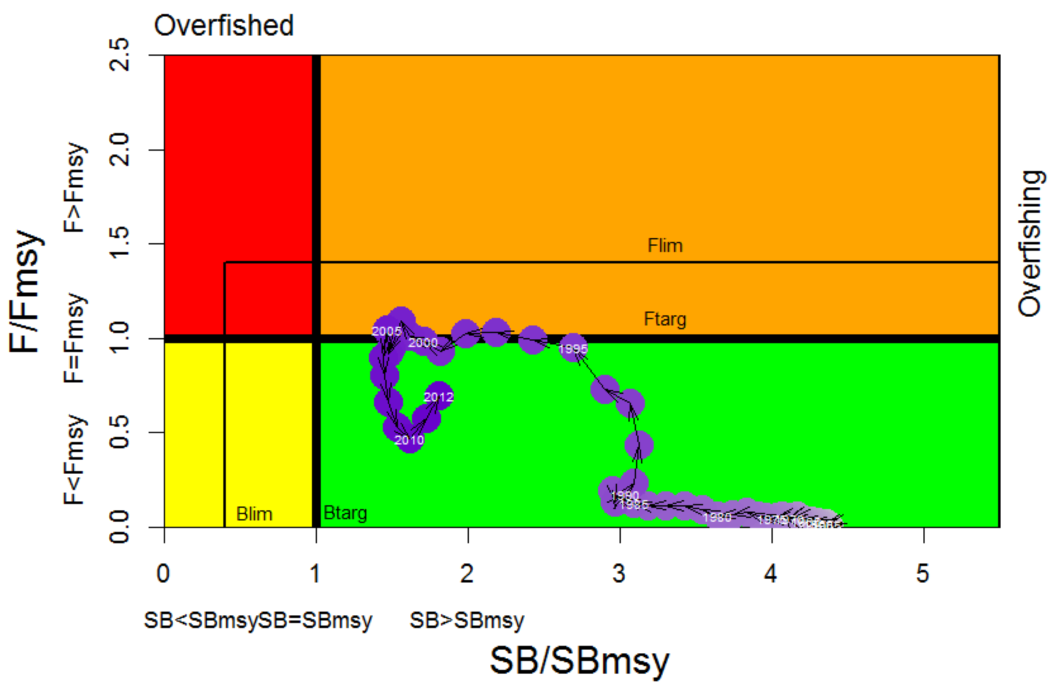


Figure 18: Kobe plot of stock trajectory using the refined base case

Table 3. Stock status summary table on the reference cases examined

Management Quantity	IO - Aggregate Indian Ocean	IO Aggregate (Japan only ref case)
Most recent catch estimate	26,016	26,016
Mean catch over last 5 years	24,579	24,579
MSY (t)	20,029 (17,972-24,085)	18,285 (15,481-21,089)
Current Data Period	1951-2012	1951-2012
F(Current)/F(MSY)	0.7 (0.48-0.91)	0.86 (0.64-1.07)
B(Current)/B(MSY)		
SB(Current)/SB(MSY)	1.59 (1.03 – 2.6)	1.36 (0.85-1.86)
B(Current)/B(0)		
SB(Current)/SB(0)	0.35 (0.24 – 0.59)	0.29 (0.18-0.4)

Alternative Base Case (Only using Japan CPUE series)

We used the same model described above with the CSIRO growth pattern, steepness (h=0.75), the low effective sample size on the length composition data, but now used the CPUE data only from Japan, and used it for the entire time series**.**

Fits to the age composition across fleets was poor (Figure 19), though fits to the Japanese CPUE by region was better as compared to equal weights across all regions (Figure 20). Selectivity appears to be fully selected by 100 cms with a small decline at around 175 cms in most fisheries (Figure 21). Fishing mortality rates seems to rise significantly in the late 90's and early 2000's with a drop after the advent of piracy (Figure 21) and spawning Biomass across regions (Figure 22) shows a steady decline (other than region 3, the southwest) though seems to steady over time for this stock. Finally the stock trajectory using a phase plot is shown for this run (Figure 23), and key elements of the base run in terms of reference points are shown in Table 3.

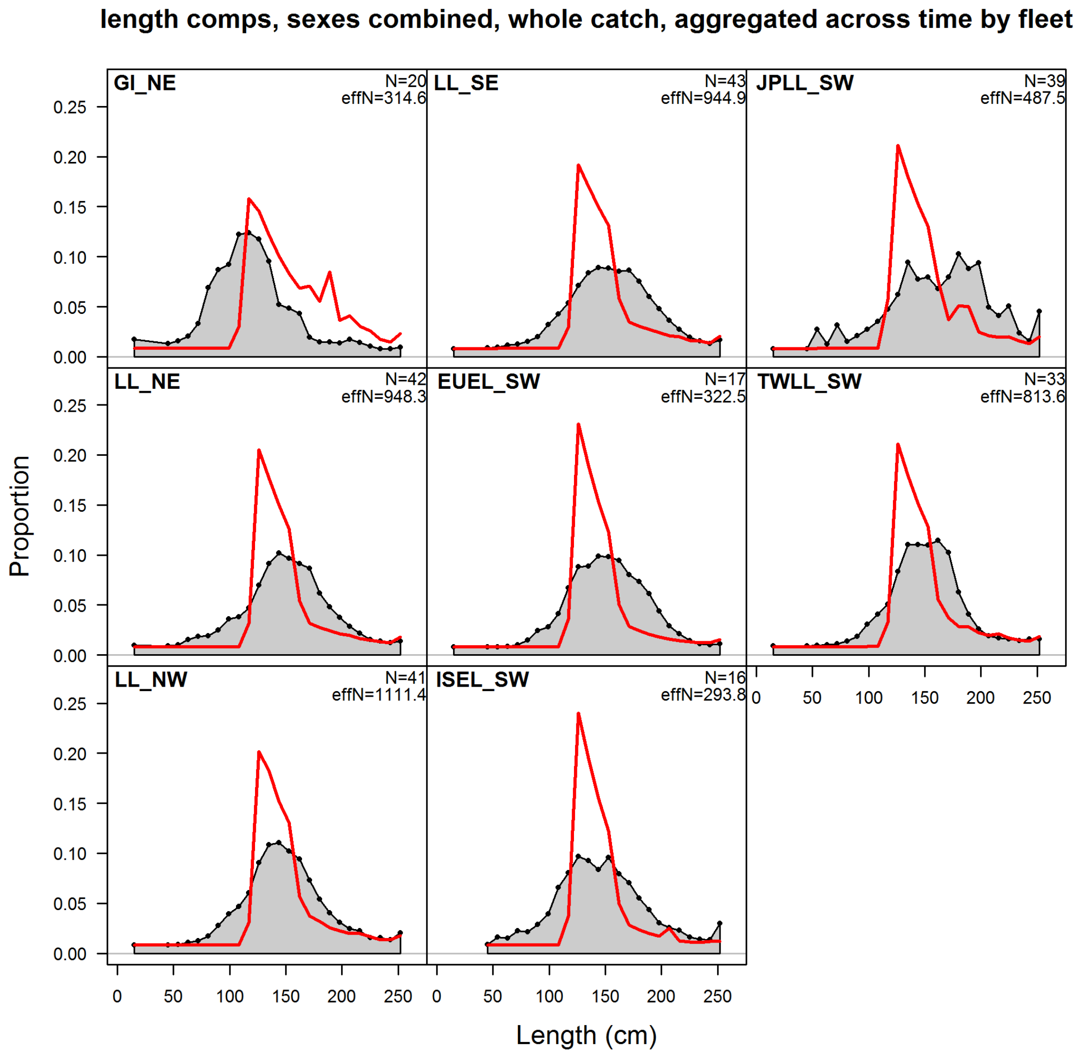


Figure 19: Fits across average length composition data estimated across fleets

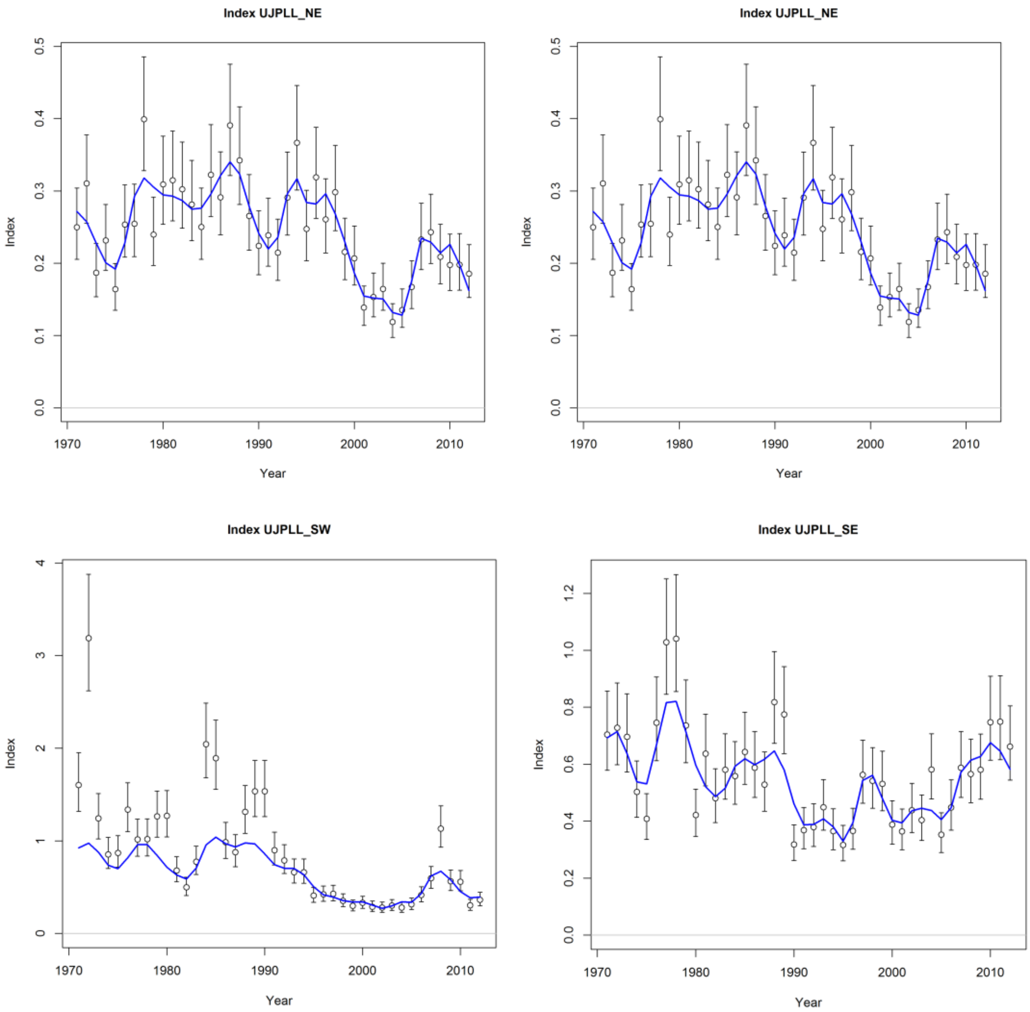


Figure 20: Fits to the standardized CPUE from Japan across different quadrants

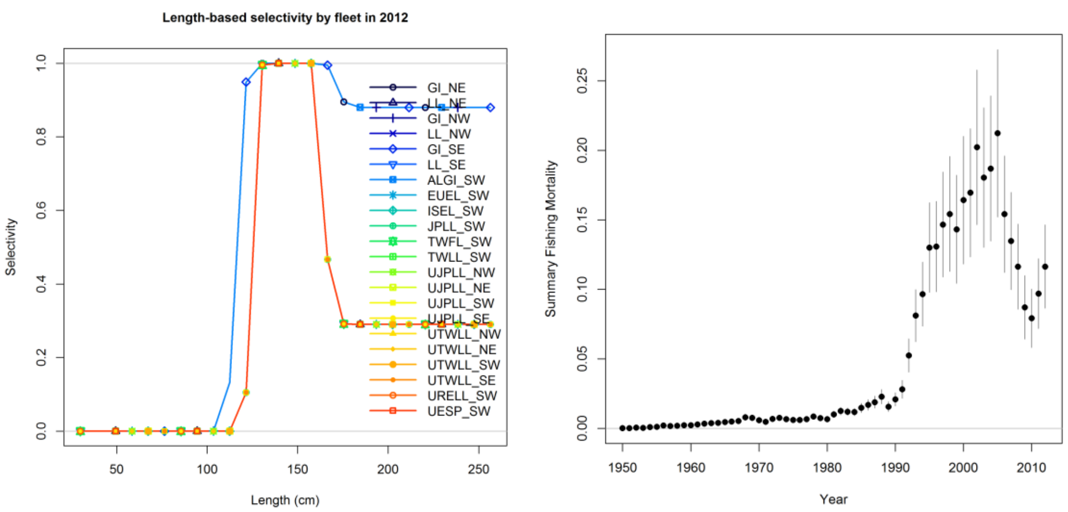


Figure 21: Selectivity patterns across fleets (left panel), and estimated F over time (right panel)

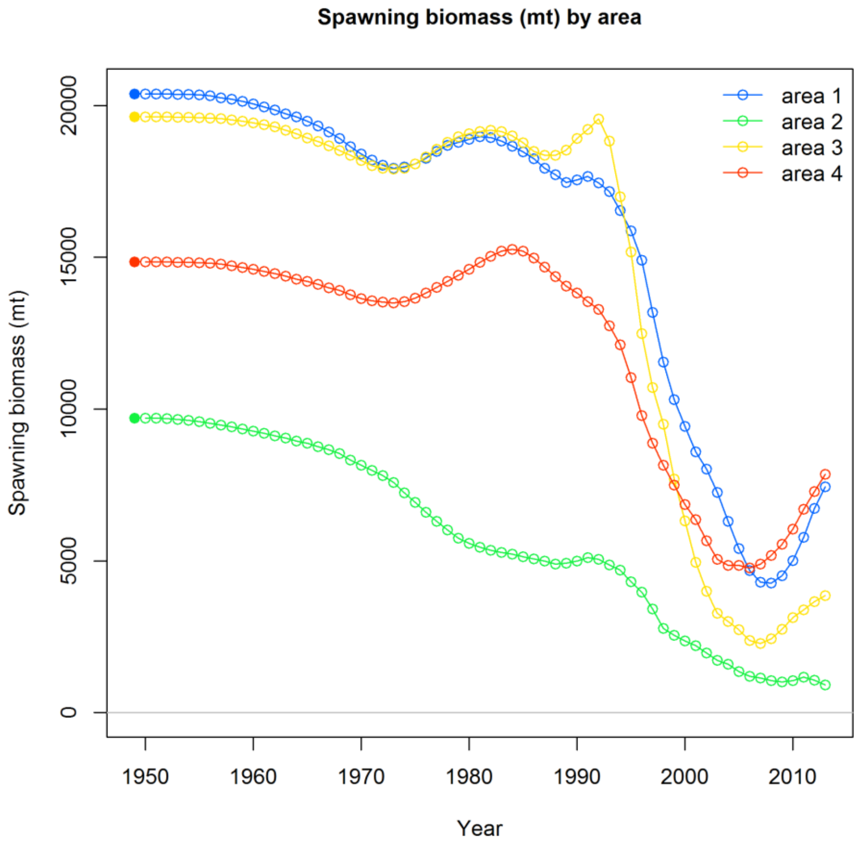


Figure 22: Spawning Biomass Trajectories across regions

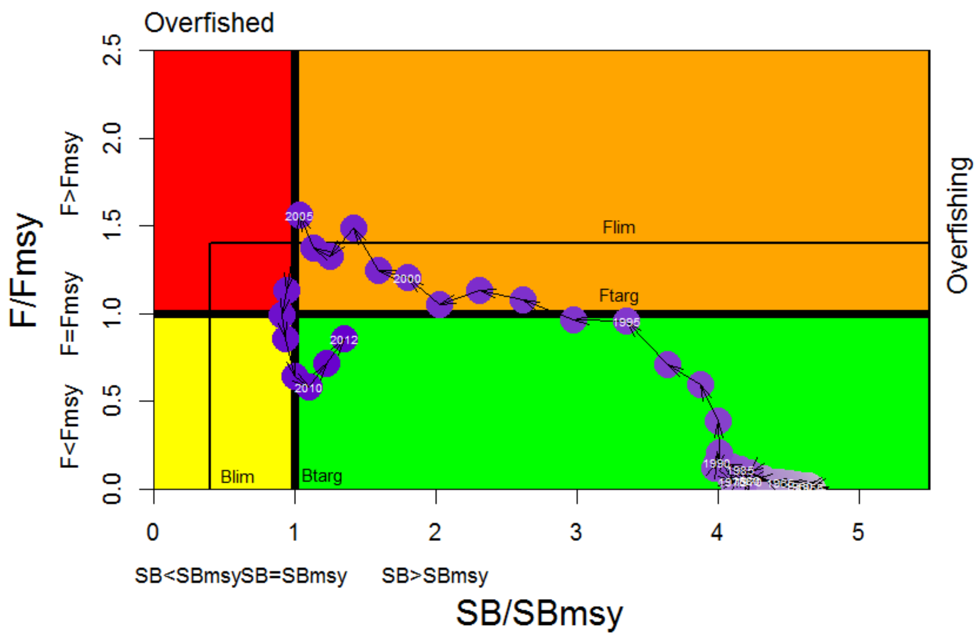


Figure 23: Phase plot for Swordfish fitting only to the Japanese CPUE data from 1971-2012.

Model uncertainties examined

Effect of growth

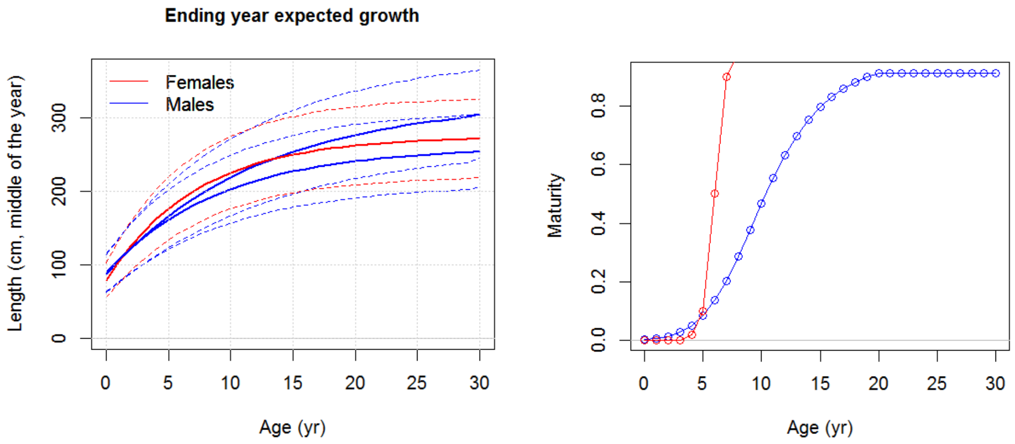


Figure 24: Slow (blue) growth based on studies conducted by Young vs. the faster growth and maturity based on studies conducted by Wang (red)

An alternative growth curve based on studies conducted by Wang et. al. (2010). The growth was intermediate, between the CSIRO growth pattern and the NMFS growth pattern that was used in 2011 (Kolody and Herrera 2011, Figure 24 above). As growth was more rapid, the target yield estimates are slightly higher than the initial run examined (Table 4)

Table 4: Derived management parameters using a faster growth curve proposed by Wang et. al. (2010).

Management Quantity	**IO - Aggregate Indian Ocean**	**IO Aggregate (Japan only ref case)**
Most recent catch estimate	26,016	26,016
Mean catch over last 5 years	24,579	24,579
MSY (t)	24K (16.7K-31.4K)	18.8K (16K-21.7K)
Current Data Period	1951-2012	1951-2012
F(Current)/F(MSY)	0.49 (0.28-0.69)	0.82 (0.6-1.02)
B(Current)/B(MSY)		
SB(Current)/SB(MSY)	2.67 (1.3-4.04)	1.67(2.09-2.25)
B(Current)/B(0)		
SB(Current)/SB(0)	0.62(0.3-0.92)	0.28 (0.25-0.51)

We examined the models from the refined base case fitting to all data and fitting only to the Japanese CPUE, and get quite a contrasting range of outcomes based on this assessment. Fits to the CPUE series for Japan, and Taiwan for the base case are shown with the faster growth curves of Taiwan (target reference points are evaluated in Table 4, Figures 25-28).

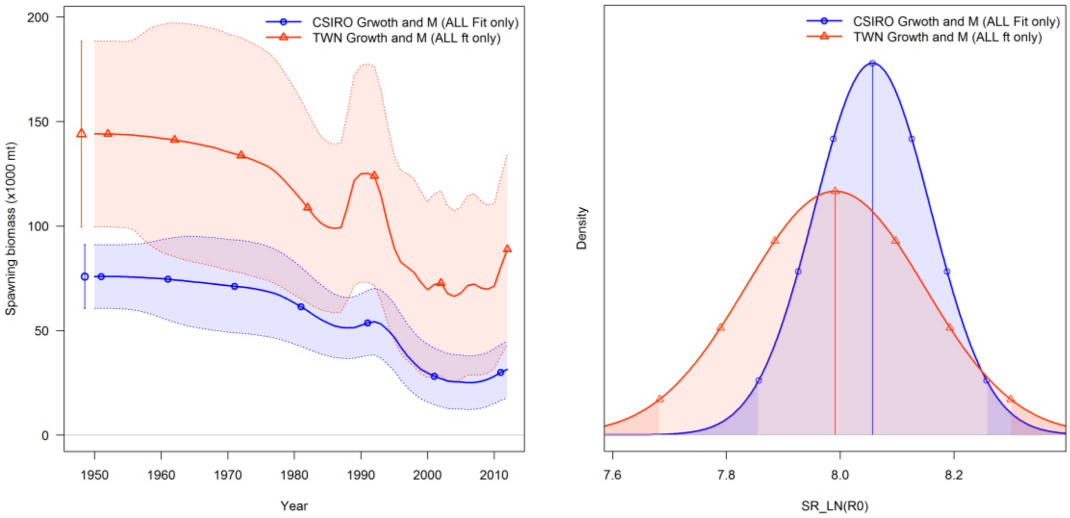


Figure 25: CSIRO growth and maturation based SSB trajectory (blue line) vs the new growth and maturation based on Taiwanese study (red lines). The left panel indicates the population trajectory while the right panel indicates the estimates of R0 (virgin recruitment) that effects the initial estimate of B0.

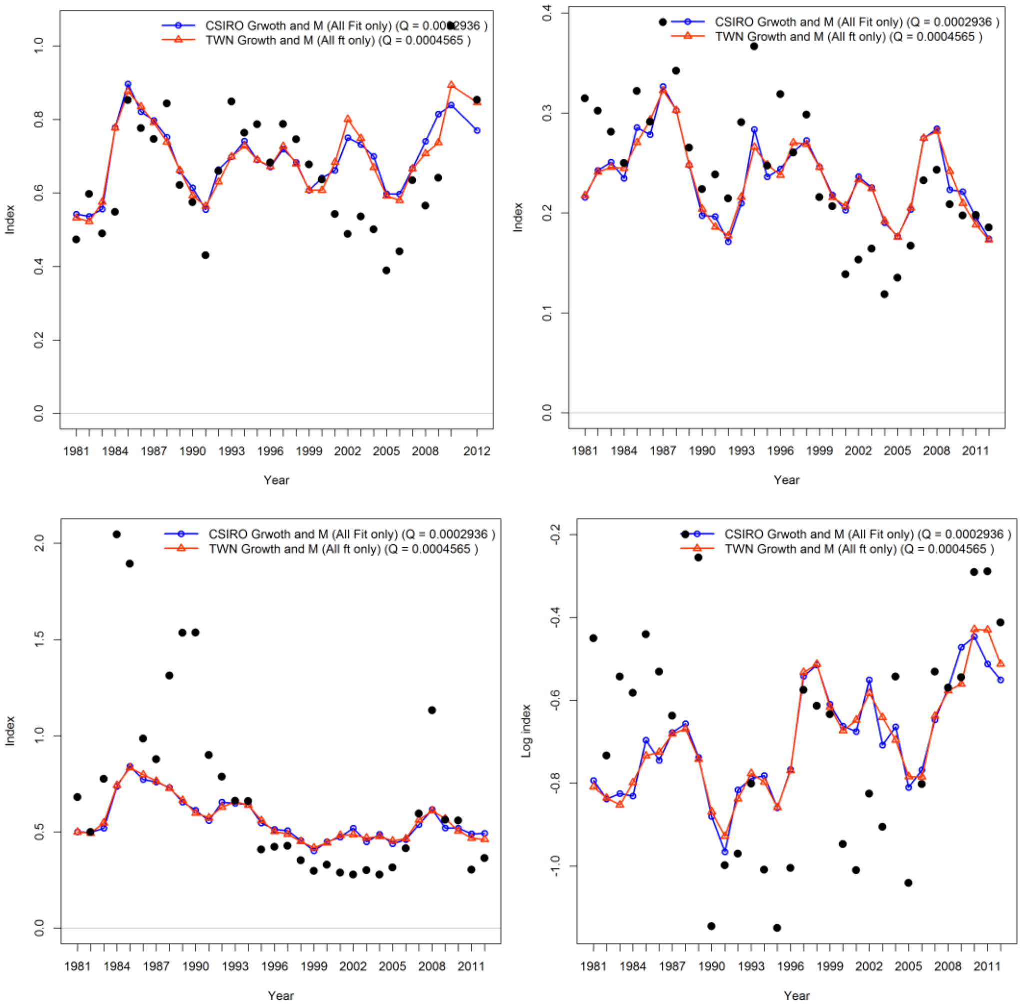


Figure 26: Fits to the Japanese CPUE when fit to all CPUE indices with equal weight

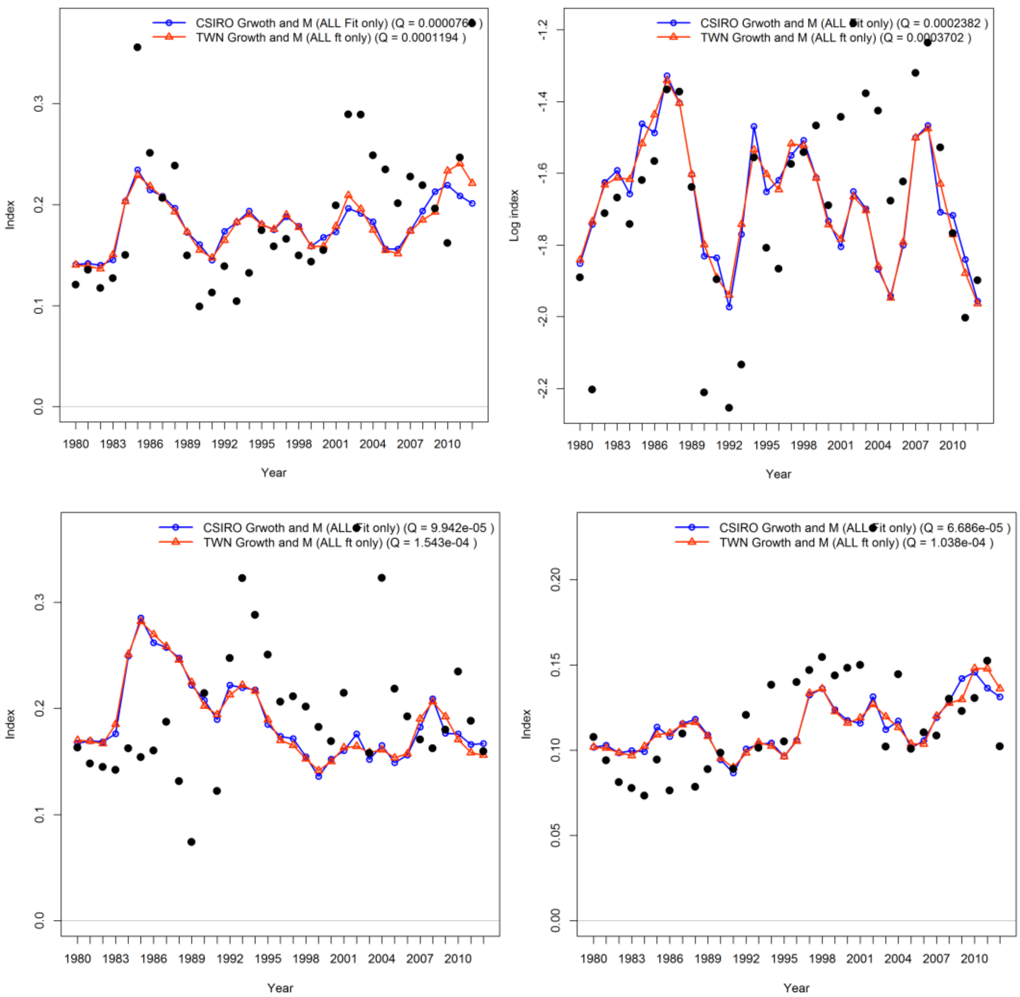


Figure 27: Fit to the Taiwanese CPUE when fit to all CPUE indices with equal weight.

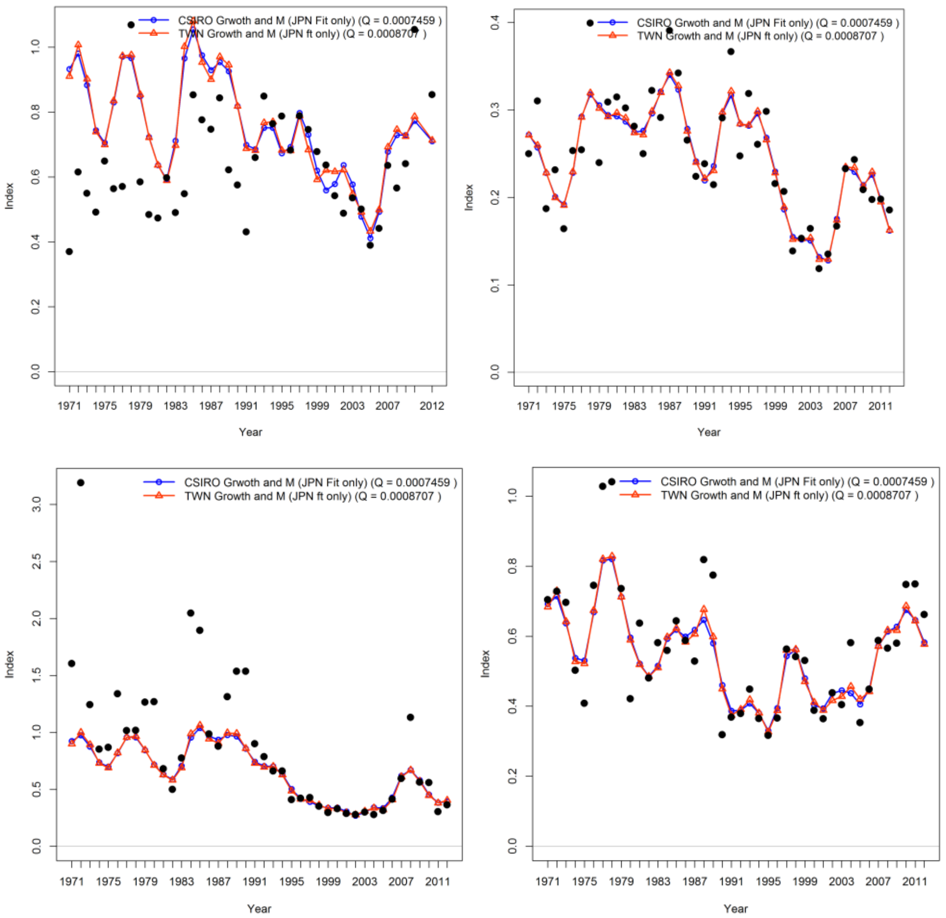


Figure 28: Fit to the Japanese CPUE when only fitting to the Japanese CPUE series.

Effect of Steepness

The higher the steepness values, the higher the yield and the lower the SSB required to optimize the yield (hence lower B0's for the highest steepness values). Fits to the data stayed quite similar (looking at Japanese CPUE only Figure 29 and the CSIRO growth curve). Similar trends are seen with the Taiwanese growth curves (not shown here).

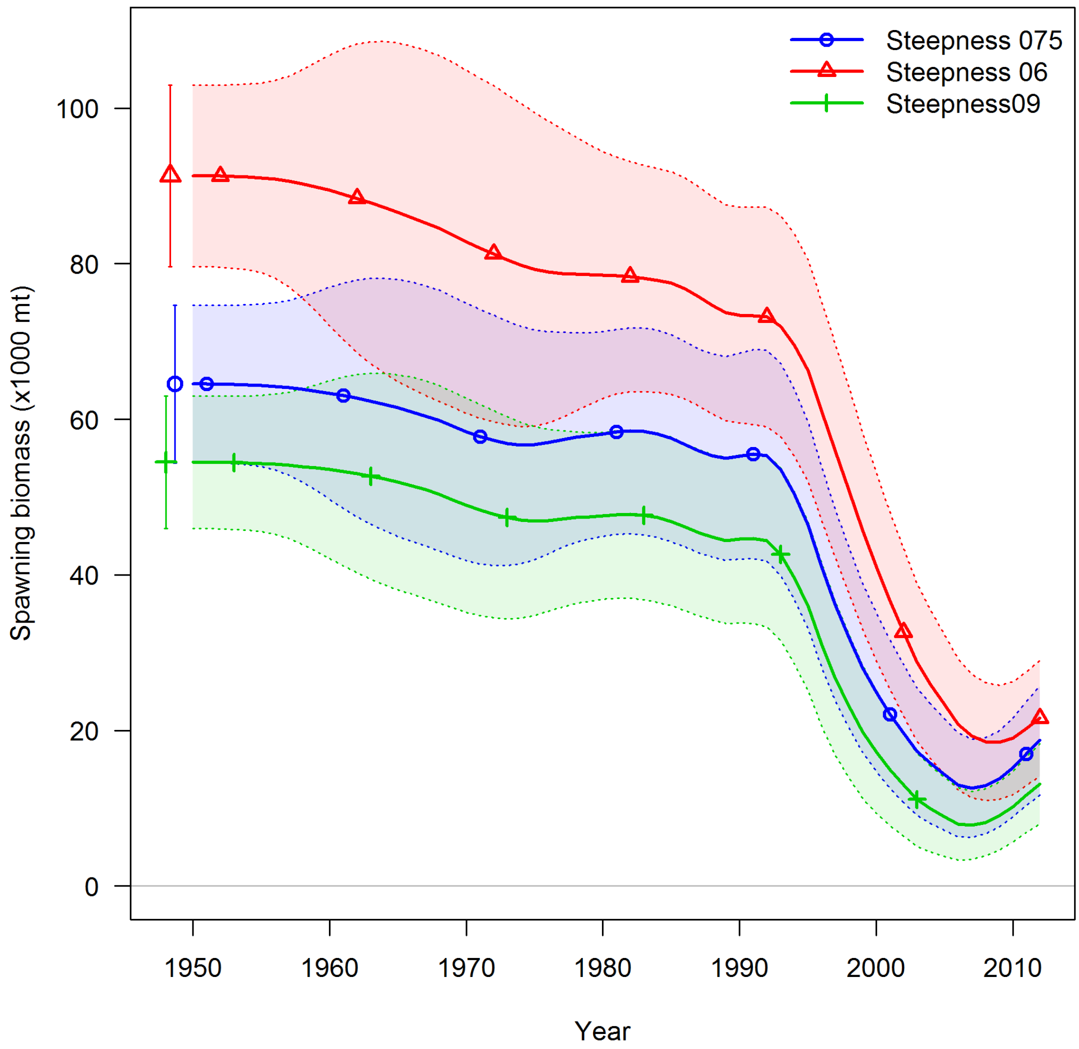
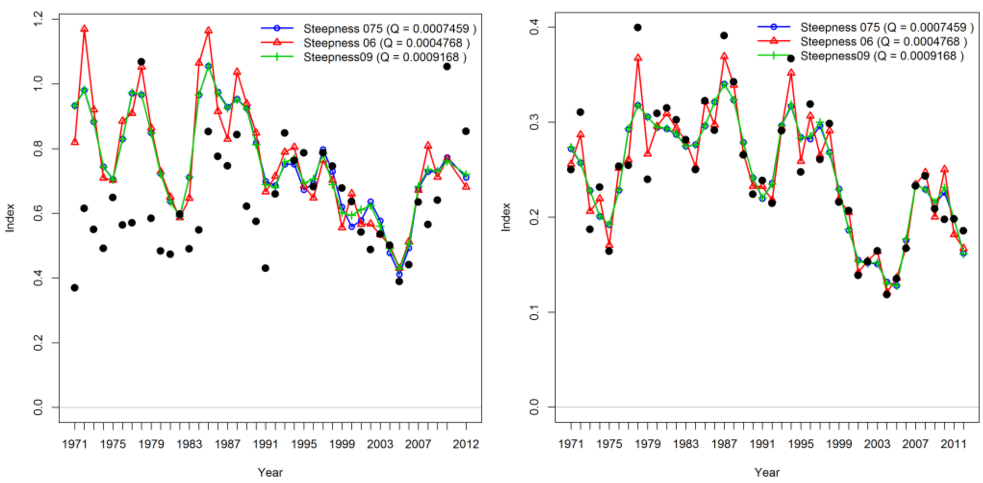


Figure 29: Effect of steepness on the Base Case Assessment using only Japanese CPUE data, and the CSIRO growth and maturation rates.



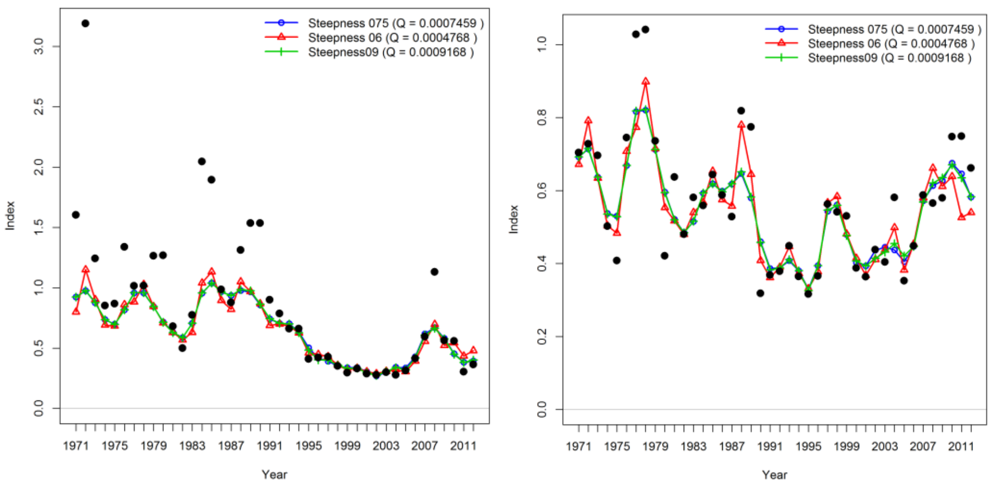


Figure 30: Effect of steepness on the Base Case Assessment using only Japanese CPUE data, and the CSIRO growth and maturation rates.

Table 5: Stock status summary table on lower and higher steepness as compared to bases case (0.75) and fit only to the Japanese CPUE data.

Management Quantity	**IO Aggregate (Japan only Steepness 0.75)**	**IO – Japan only Steepness 0.6**	**IO – Japan only Steepness 0.9**
Most recent catch estimate	26,016	26,016	26,016
Mean catch over last 5 years	24,579	24,579	24,579
MSY (t)	18,285 (15,481-21,089)	15.8 Kt (13.9 Kt-17.7 Kt)	20.37 Kt (17.2 Kt-23.5 Kt)
Current Data Period	1951-2012	1951-2012	1951-2012
F(Current)/F(MSY)	0.86 (0.64-1.07)	1.35 (1.03-1.67)	0.65 (0.49-0.82)
B(Current)/B(MSY)			
SB(Current)/SB(MSY)	1.36 (0.85-1.86)	0.7 (0.43-0.96)	1.85 (1.12-2.58)
B(Current)/B(0)			
SB(Current)/SB(0)	0.29 (0.18-0.4)	0.21 (0.13-0.29)	0.24 (0.15-0.34)

Effect of Weighting the size data differently

Extreme values of highly weighting the length frequency data to capture the length frequencies from the longline fleets yielded a somewhat different picture of the dynamics of the population (Figure 32).

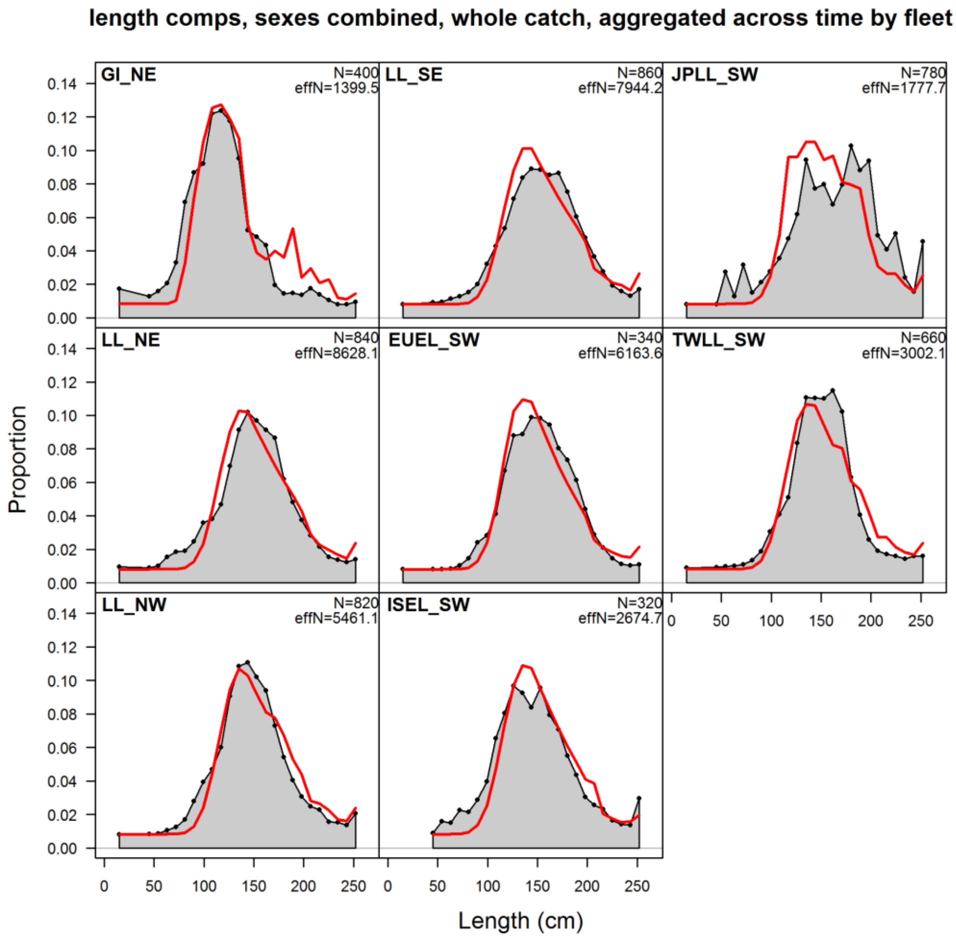


Figure 31: Average length frequency captured by a model that highly weighs the LF data

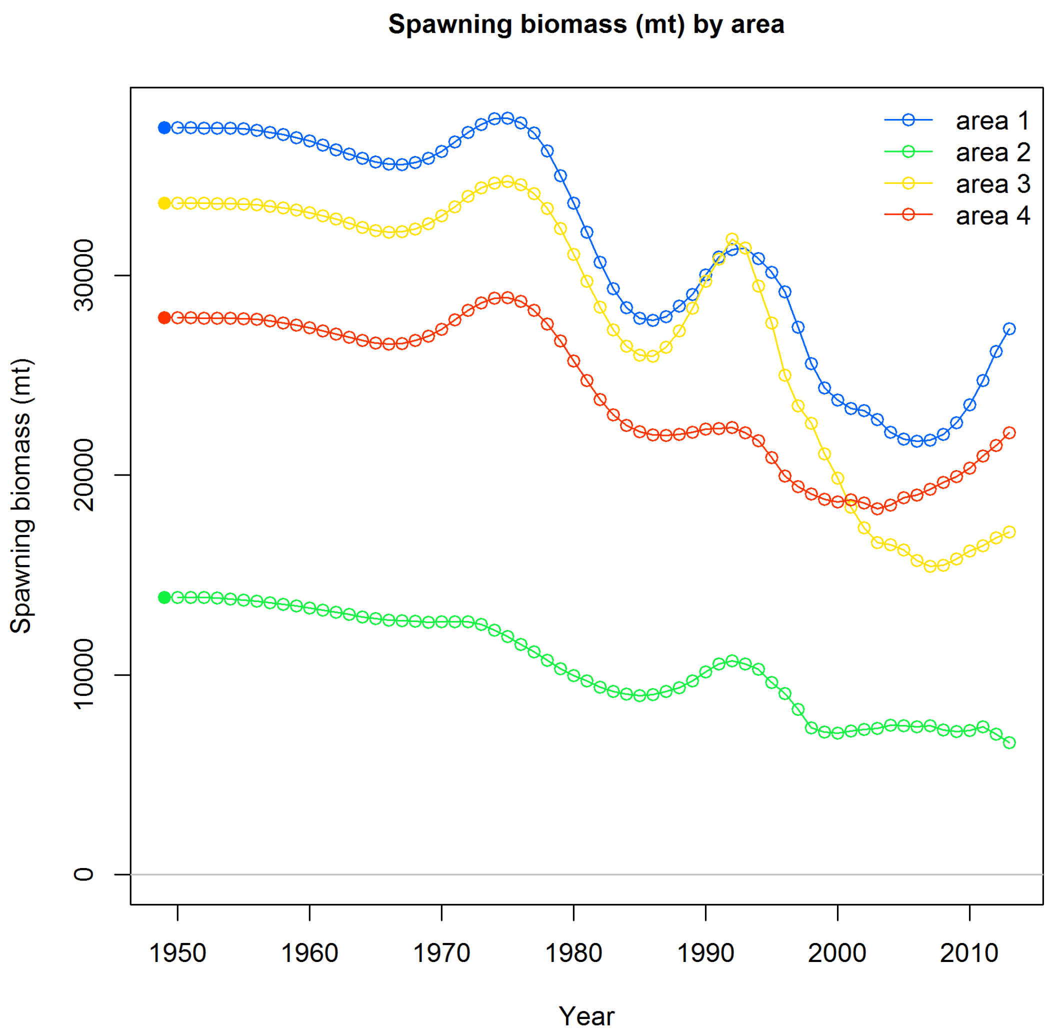


Figure 32: Spawning Biomass Trajectories of the different areas in the Indian Ocean

Based on this model the overall sustainable yield targets were a lot higher (around 31K, Table 6), and the stock never ever went into a trajectory that seemed that either the fishing mortality may have been too high or that the stock was overfished (Figure 33). However, giving such a high weight to the length composition data is not a good practice, as we maybe over fitting the age comp data at the cost of the index of abundance (Francis 2011), and it would be better to fit to the index of abundance rather than the age composition data.

Table 6. Stock status summary table on the reference cases examined with high effective sampling size on length frequency data

Management Quantity	IO - Aggregate Indian Ocean	IO Aggregate (Japan only ref case)
Most recent catch estimate	26,016	26,016
Mean catch over last 5 years	24,579	24,579
MSY (t)	30588 (24K-37.1K)	31140 (22.4Kt-39.8Kt)
Current Data Period	1951-2012	1951-2012
F(Current)/F(MSY)	0.36 (0.3-0.42)	0.44 (0.32-0.55)
B(Current)/B(MSY)		
SB(Current)/SB(MSY)	2.09 (1.73-4.06)	2.08 (1.37-2.08)
B(Current)/B(0)		

SB(Current)/SB(0)	0.65 (0.38-0.91)	0.46 (0.30-0.62)

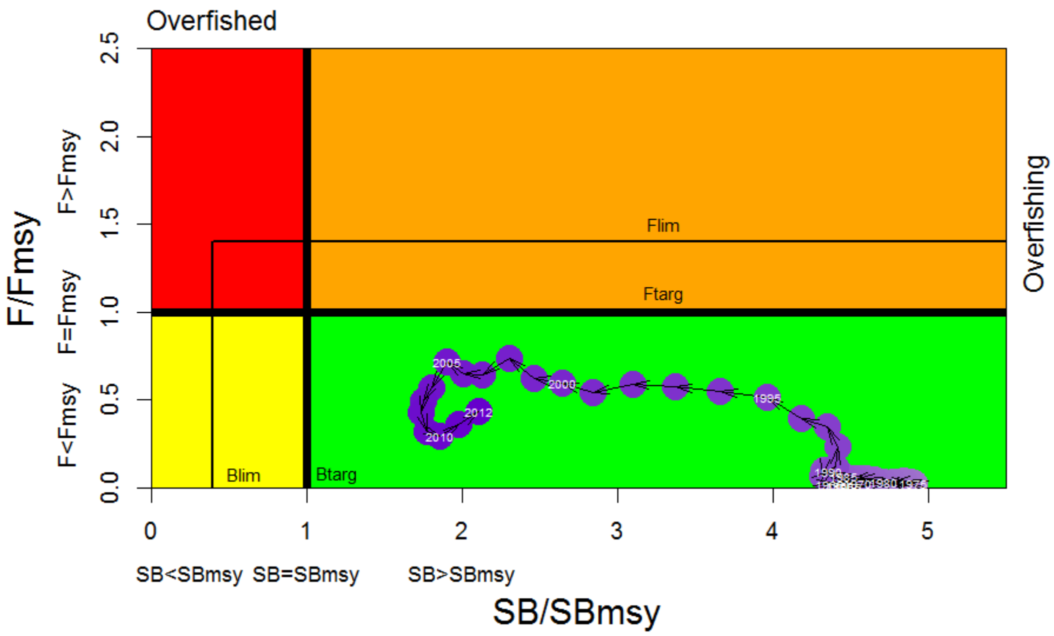


Figure 33: Phase plot showing the stock trajectory with a higher effective sample size for the length comp data and revised base case above

Effect of Uncertainty across the range of models analysed

A summary of all models run using the CSIRO growth curve, maturation and natural mortality rates is show in Figure 34 below.

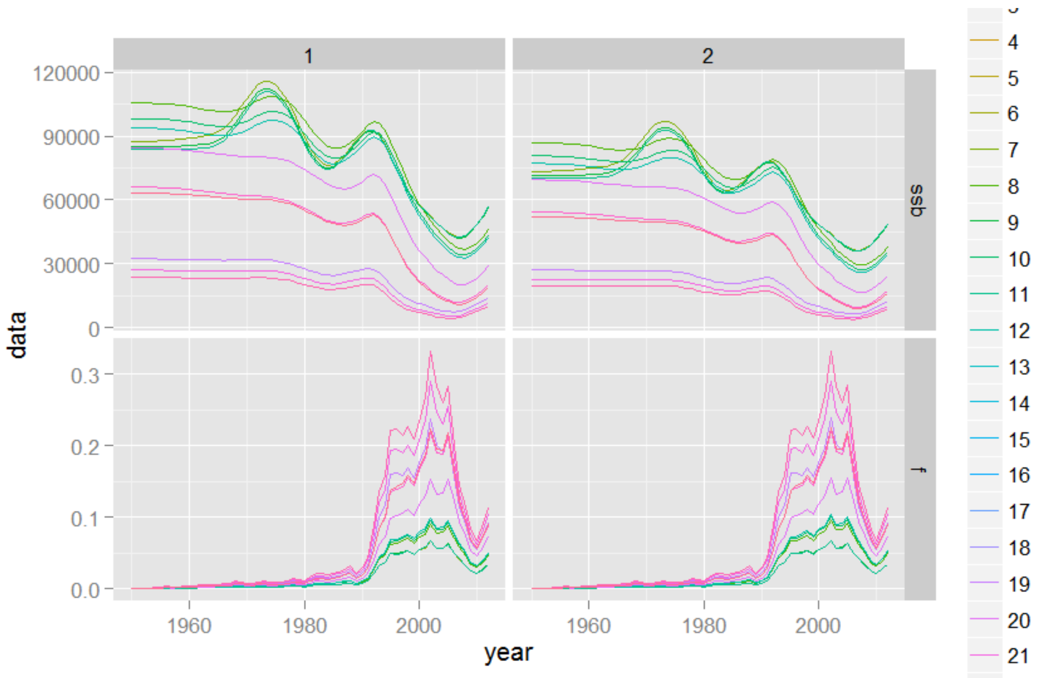


Figure 34: All runs examined using the CSIRO growth curve, delayed maturation rates, and natural mortality values of 0.25 or 0.4 along with fitting to the Japanese CPUE data separately or with all the fleets (1 indicates males and 2 females).

If we use the range of these values, we get an uncertainty estimate on key characteristics, namely recruitment, SSB, and F's by males (blue) and females (red) as shown in Figure 35 below.

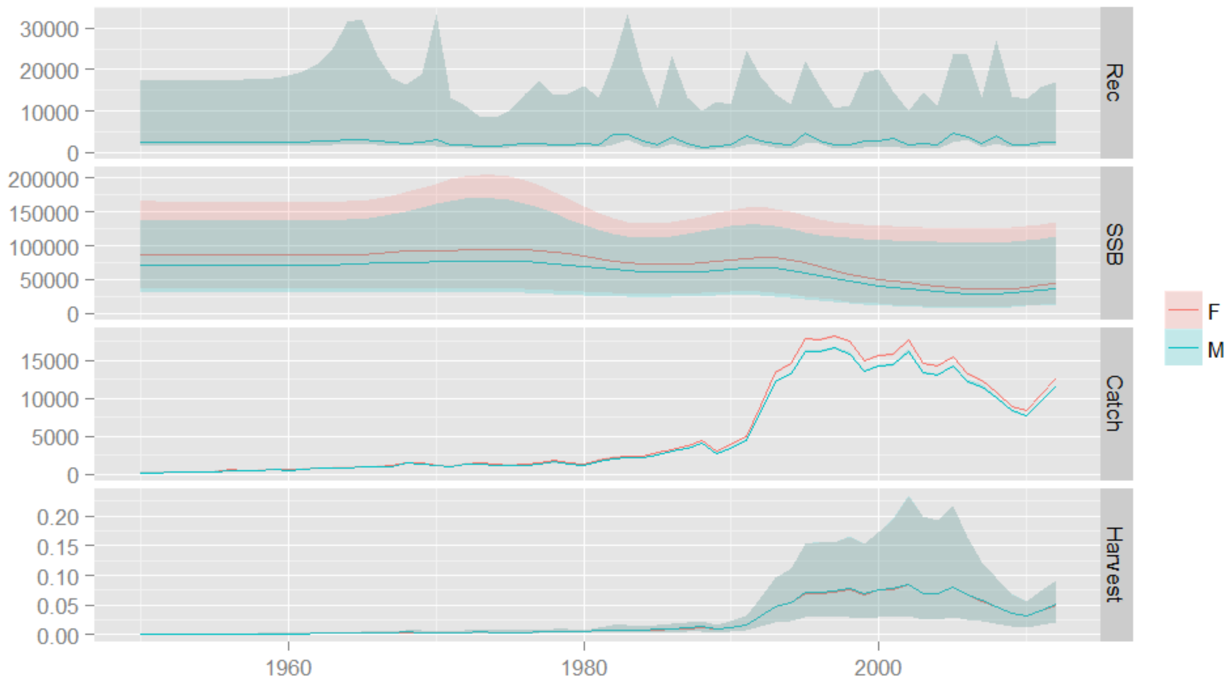


Figure 35: Uncertainty estimated as a function of the structural uncertainty in parameter values, and whether we fit to the CPUE index across all fleets or Japan (with common q) only.

Results and variations in the runs are shown in Table 7 below. As indicated by the likelihoods (the ESS likelihoods being different in some cases) the survey component remains fairly consistent as well as the length composition components, thus implying that all these models are plausible in describing the dynamics of SWO in the Indian Ocean.

Similar summaries are run for the Taiwanese growth curve datasets, and the corresponding outcomes are reported in Figures 36 and 37, and Table 8.

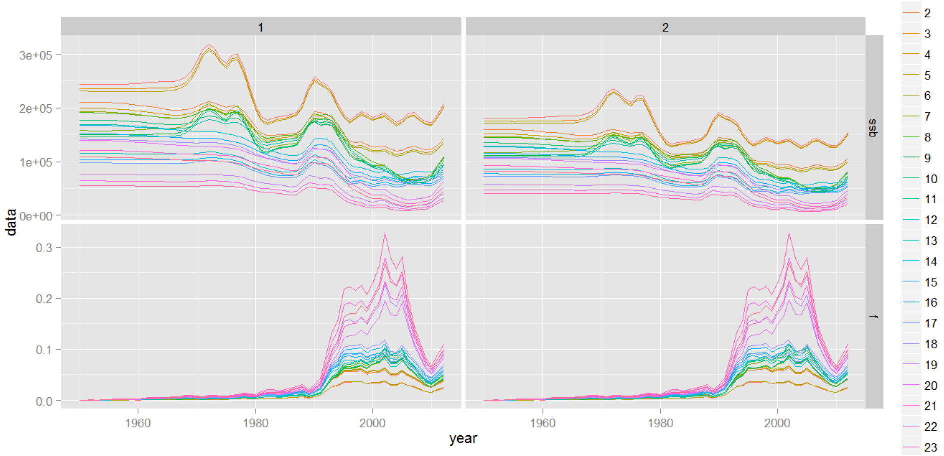


Figure 36: All runs examined using the CSIRO growth curve, delayed maturation rates, and natural mortality values of 0.25 or 0.4 along with fitting to the Japanese CPUE data separately or with all the fleets (1 indicates males and 2 females).

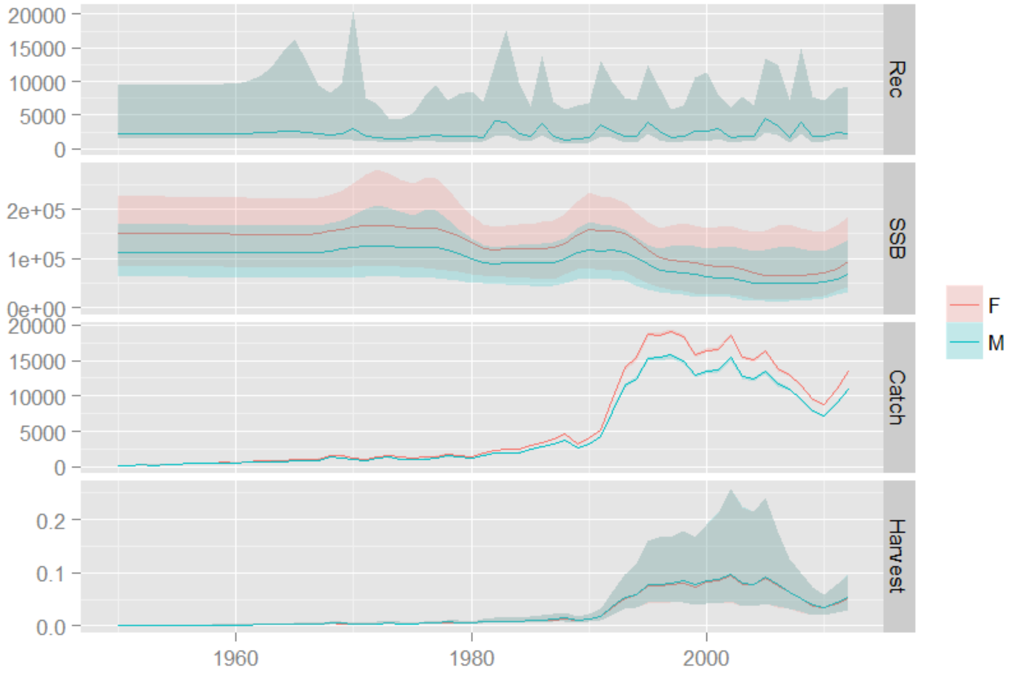


Figure 37: Uncertainty estimated as a function of the structural uncertainty in paarmter values, and whether we fit to the CPUE index across all fleets or Japan (with common q) only.

Table 7: 24 runs using different M's effective samples sizes, and Japanese CPUE in conjunction with others to assess goodness of fit (CSIRO Database)

Run	M	steepness	LLJPN (1=all, 0 =JPN)	ess	id	SPB_1950	SSB_MSY	SPB_2012	F_2012	F_MSY	TotYield_MSY	LIKELIHOOD	FinalGradient	Survey	Length_comp	SB/SB0	SB/MSY	F/MSY
1	0.4	0.6	1	1	1_M0.4_st	87468	22936	56482	0.03	0.12	54799	989.5	6.59E-05	-6.2	840.4	0.65	2.46	0.24
2	0.25	0.6	1	1	2_M0.25_	105468	30422	46033	0.06	0.09	22181	983.4	5.67E-01	-0.8	847.1	0.44	1.51	0.66
3	0.4	0.75	1	1	3_M0.4_st	84874	16342	56083	0.03	0.17	73295	989.6	2.81E-03	-6.2	840.3	0.66	3.43	0.17
4	0.25	0.75	1	1	4_M0.25_	98105	21817	43297	0.06	0.12	27196	982.3	3.49E-02	-0.9	847.4	0.44	1.98	0.48
5	0.4	0.9	1	1	5_M0.4_st	83903	9242	56400	0.03	0.27	100435	989.8	3.89E-04	-6.2	840.3	0.67	6.10	0.10
6	0.25	0.9	1	1	6_M0.25_	93724	13264	41857	0.06	0.19	33737	981.8	9.50E-05	-1.0	847.5	0.45	3.16	0.32
7	0.4	0.6	0	1	7_M0.4_st	87468	22936	56482	0.03	0.12	54799	989.5	6.59E-05	-6.2	840.4	0.65	2.46	0.24
8	0.25	0.6	0	1	8_M0.25_	105468	30422	46033	0.06	0.09	22181	983.4	5.67E-01	-0.8	847.1	0.44	1.51	0.66
9	0.4	0.75	0	1	9_M0.4_st	84874	16342	56083	0.03	0.17	73295	989.6	2.81E-03	-6.2	840.3	0.66	3.43	0.17
10	0.25	0.75	0	1	10_M0.25	98105	21817	43297	0.06	0.12	27196	982.3	3.49E-02	-0.9	847.4	0.44	1.98	0.48
11	0.4	0.9	0	1	11_M0.4_	83903	9242	56400	0.03	0.27	100435	989.8	3.89E-04	-6.2	840.3	0.67	6.10	0.10
12	0.25	0.9	0	1	12_M0.25	93724	13264	41857	0.06	0.19	33737	981.8	9.50E-05	-1.0	847.5	0.45	3.16	0.32
13	0.4	0.6	1	0.1	13_M0.4_	32249	8342	13880	0.09	0.12	20942	118.9	2.18E-02	-61.3	139.2	0.43	1.66	0.74
14	0.25	0.6	1	0.1	14_M0.25	84418	24433	28664	0.08	0.09	17647	121.2	1.75E-03	-47.7	129.5	0.34	1.17	0.93
15	0.4	0.75	1	0.1	15_M0.4_	26965	5088	11128	0.11	0.18	24366	116.8	2.55E-02	-64.7	142.1	0.41	2.19	0.58
16	0.25	0.75	1	0.1	16_M0.25	65998	14470	20236	0.10	0.13	18791	118.9	2.61E-03	-46.8	128.8	0.31	1.40	0.80
17	0.4	0.9	1	0.1	17_M0.4_	23540	2491	9533	0.12	0.30	29868	115.5	2.15E-02	-67.3	144.5	0.40	3.83	0.40
18	0.25	0.9	1	0.1	18_M0.25	63255	8907	18745	0.11	0.19	22874	116.4	8.46E-04	-50.4	130.7	0.30	2.10	0.55
19	0.4	0.6	0	0.1	19_M0.4_	32249	8342	13880	0.09	0.12	20942	118.9	2.18E-02	-61.3	139.2	0.43	1.66	0.74
20	0.25	0.6	0	0.1	20_M0.25	84418	24433	28664	0.08	0.09	17647	121.2	1.75E-03	-47.7	129.5	0.34	1.17	0.93
21	0.4	0.75	0	0.1	21_M0.4_	26965	5088	11128	0.11	0.18	24366	116.8	2.55E-02	-64.7	142.1	0.41	2.19	0.58
22	0.25	0.75	0	0.1	22_M0.25	65998	14470	20236	0.10	0.13	18791	118.9	2.61E-03	-46.8	128.8	0.31	1.40	0.80
23	0.4	0.9	0	0.1	23_M0.4_	23540	2491	9533	0.12	0.30	29868	115.5	2.15E-02	-67.3	144.5	0.40	3.83	0.40
24	0.25	0.9	0	0.1	24_M0.25	63255	8907	18745	0.11	0.19	22874	116.4	8.46E-04	-50.4	130.7	0.30	2.10	0.55

Table 8: 24 runs using different M's effective samples sizes, and Japanese CPUE in conjunction with others to assess goodness of fit (TWN Database)

Run	M	steepness	LLJPN (1=all, 0 =JPN)	ess	id	SPB_1950	SSB_MSY	SPB_2012	F_2012	F_MSY	TotYield_MSY	LIKELIHOOD	FinalGradient	Survey	Length_comp	SB/SB0	SB/MSY	F/MSY
1	0.4	0.6	1	1	1_M0.4_st	243466	67499	207177	0.02	0.12	65997	1445.4	5.63E-05	485.8	827.6	0.85	3.07	0.18
2	0.25	0.6	1	1	2_M0.25_	210777	63744	143583	0.05	0.10	24598	1448.7	6.09E-05	489.6	833.7	0.68	2.25	0.50
3	0.4	0.75	1	1	3_M0.4_st	235446	49025	202749	0.02	0.16	85676	1445.1	2.51E-04	485.7	827.5	0.86	4.14	0.13
4	0.25	0.75	1	1	4_M0.25_	199342	47376	137526	0.05	0.14	30040	1447.8	8.20E-05	489.5	833.7	0.69	2.90	0.36
5	0.4	0.9	1	1	5_M0.4_st	231216	28844	200758	0.02	0.24	112521	1444.9	2.23E-04	485.7	827.4	0.87	6.96	0.09
6	0.25	0.9	1	1	6_M0.25_	192580	30208	134040	0.05	0.20	36738	1447.3	2.96E-04	489.4	833.7	0.70	4.44	0.25
7	0.4	0.6	0	1	7_M0.4_st	157577	43537	109308	0.04	0.12	42879	959.6	1.31E-04	-15.0	830.6	0.69	2.51	0.32
8	0.25	0.6	0	1	8_M0.25_	191080	57752	100675	0.06	0.10	22286	966.4	8.87E-05	-8.6	841.4	0.53	1.74	0.64
9	0.4	0.75	0	1	9_M0.4_st	150006	31100	106697	0.04	0.17	54882	959.4	2.69E-05	-15.2	830.6	0.71	3.43	0.23
10	0.25	0.75	0	1	10_M0.25	177491	42112	95250	0.06	0.14	26761	965.0	1.62E-04	-8.9	841.8	0.54	2.26	0.47
11	0.4	0.9	0	1	11_M0.4_	146352	18184	106096	0.04	0.25	71719	959.4	1.44E-04	-15.3	830.6	0.72	5.83	0.16
12	0.25	0.9	0	1	12_M0.25	169375	26491	92311	0.07	0.20	32365	964.3	4.19E-05	-9.1	842.0	0.55	3.48	0.32
13	0.4	0.6	1	0.1	13_M0.4_	115209	31781	82562	0.05	0.12	31843	607.7	8.31E-05	454.4	128.3	0.72	2.60	0.41
14	0.25	0.6	1	0.1	14_M0.25	167561	51205	95805	0.07	0.10	19658	607.3	7.45E-05	452.8	123.1	0.57	1.87	0.69
15	0.4	0.75	1	0.1	15_M0.4_	103928	21452	74449	0.05	0.17	38678	607.2	9.31E-05	453.8	128.9	0.72	3.47	0.31
16	0.25	0.75	1	0.1	16_M0.25	151445	36564	85667	0.07	0.13	22841	605.9	6.35E-05	451.9	123.6	0.57	2.34	0.54
17	0.4	0.9	1	0.1	17_M0.4_	97572	11951	70091	0.06	0.26	48796	606.9	9.12E-05	453.4	129.2	0.72	5.86	0.22
18	0.25	0.9	1	0.1	18_M0.25	141521	22789	79623	0.08	0.20	26865	605.0	2.61E-05	451.3	123.9	0.56	3.49	0.38
19	0.4	0.6	0	0.1	19_M0.4_	76980	20962	40113	0.09	0.12	21548	105.0	1.25E-04	-67.5	131.9	0.52	1.91	0.73
20	0.25	0.6	0	0.1	20_M0.25	139555	42014	62723	0.09	0.10	16911	113.2	6.94E-05	-52.5	125.6	0.45	1.49	0.96
21	0.4	0.75	0	0.1	21_M0.4_	64045	12961	31774	0.11	0.18	24332	102.3	8.36E-05	-70.9	134.3	0.50	2.45	0.60
22	0.25	0.75	0	0.1	22_M0.25	121356	28495	52155	0.11	0.14	19056	109.0	5.46E-05	-54.9	126.9	0.43	1.83	0.77
23	0.4	0.9	0	0.1	23_M0.4_	55139	6583	26421	0.12	0.27	28432	100.5	9.87E-05	-73.8	136.7	0.48	4.01	0.45
24	0.25	0.9	0	0.1	24_M0.25	108299	16485	44945	0.12	0.21	21666	106.0	9.29E-05	-57.1	128.3	0.42	2.73	0.56

Kobe 2 Projections

TO BE COMPLETED

Table 8. Kobe 2 Strategy Matrix for Aggregate Indian Ocean. Probability (expressed as a percentage of the distribution of models weighted as in Error! Reference source not found.**) of exceeding the MSY-based spawning biomass and fishing mortality reference points.**

IO	Constant Catch Level (relative to 2012)				
	60%	80%	100%	120%	140%
B(2015) <B(MSY)					
F(2015) >F(MSY)					
B(2022) <B(MSY)					
F(2022) >F(MSY)					

Stock Status Synthesis

It is clear that there are large uncertainties in the biology and data that underpin this assessment, such that it would be difficult to defend the selection of a unique model to adequately represent the stock status. Table 10 shows the range of uncertainty across all models:

Table 10: Results across all models examined in Tables 7and 8 (ranges are plausible ranges, and points are median values)

Management Quantity	IO - Aggregate Indian Ocean
Most recent catch estimate	26,016
Mean catch over last 5 years	24,579
MSY (t)	27.1K (16.8 K-112.5 K)
Current Data Period	1951-2012
F(Current)/F(MSY)	0.46 (0.09-0.96)
B(Current)/B(MSY)	
SB(Current)/SB(MSY)	2.46 (1.17-6.96)
B(Current)/B(0)	
SB(Current)/SB(0)	0.52 (0.3-0.87)

1. Steepness –the lower h=0.6 value seems to be too low given the life history of this species. However, we would hesitate to claim that it is impossible. The h=0.9 option seems to be on the higher end of results generally found for tuna stocks (ISSF 2011), and seems unlikely, but more likely than h=0.6.
    - Observations of other SWO populations which have experienced a decrease in fishing effort seem to show a rapid population rebound (e.g. Hawai'i, North Atlantic, SW Pacific), and this may currently be happening in the western Indian Ocean. Together with life history considerations, this suggests that the higher steepness values are probably more likely for this species.

2. Growth, mortality and maturity We do not have a strong preference among the two growth curves and more work needs to be done to get better estimates of growth though both ranges could be plausible given variation in growth rates over time

3. Low effective sample sizes don't adequately capture the size selectivity in the fishery and more detailed investigations need to be made to assess whether one should put more weight on this dataset. When conflicting signals are obtained from the alternative datasets, it is often the tendency to weight the CPUE higher than the size-composition (Francis 2011)> however we presented two extreme case; one with very low ESS for the size sample data (20), and another with a very high ESS (200).

4. CPUE series – the stock status seems to be robust to the inclusion or exclusion of ESP and POR CPUE series. We would tend to trust the POR and ESP series more than the others because: i) These fleets seem to have operated consistently over the short time periods, and ii) the standardization analyses were very robust to different assumptions. We would tend to have the least confidence in the TWN fleet because we know that it has a history of shifting targeting, that we cannot quantify very well (including toward, and probably away from, SWO). We have similar doubts about the JPN fleet, but the targeting shifts are likely more subtle than TWN because SWO has never been reported as a main target species for JPN. However, we have some concern about the magnitude of the steep JPN CPUE decline in the 1990s because i) the timing of the shift is sensitive to spatial assumptions, ii) the decline occurs too quickly to be completely explained by the catch history and anomalous recruitment (though there is an interaction here with the assumed CPUE errors). However, given that when including the entire time series from the 1970's from Japan mad the model estimate very high R0 and B0 levels indicates that the steep decline in the 1970;s and then again in the 1990's may have some problems with the standardization approach. In the Japan only model investigated the model capture the dynamics of the drop in abundance well, explained primarily by poor recruitment, and since it's the longest consistently collected dataset on the Indian Ocean choose to value this analysis, and keep it as one of the plausible outcomes from the model.

Future Recommendations

1. Further consideration of all the CPUE series is warranted, but in particular, different methods to account for (and express the uncertainty associated with) the targeting shifts in the Japanese and Taiwanese fleets should be continued.
2. The representativeness of the size composition data merits further consideration, as the way we weigh the data has considerable management implications. More direct validation using log-books may address this problem. Alternatively, we could fit to the EU fleets only and use the estimated selectivity for the Taiwanese and Japanese fleets.
3. Age estimation methods should be revisited with direct validation methods. The sizable Atlantic swordfish tag recovery data set may provide the best basis from which to verify age-length relationships, and the different age estimation procedures should be formally compared in a manner similar to that described in Young et al. 2008.
4. We recommend that Management Strategy Evaluation (MSE) should be used to develop manage procedures that are robust to the major uncertainties in the stock, with a primary emphasis on the SW region. As long as effort levels remain stable or continue to decline (due to piracy or other economic factors), there does not seem to be an urgent need for disruptive management action. This may create an effective time window where MSE could be pursued in preparation for the eventual return to historical fishing patterns, or the development of the coastal fleets.

Conclusions:

1. This assessment represents 48 plausible outcomes of the assessment based primarily on the more thorough investigation done in 2011 (Kolody and Herrera 2011) that attempts to quantify the stock status, and the uncertainty associated with several key assumptions. The stock status is sensitive to some important factors including stock recruit steepness and growth/Mortality.

2. While there remain concerns about some of the data and assumptions, there are some reasonably robust stock status inferences:
    - Recent declines in catch and effort have substantially reduced the fishing pressure on the swordfish population.
    - There appears to be a relatively low risk that the Indian Ocean swordfish population as a whole is either overfished or experiencing overfishing. Reference points below correspond to the median and minimum and maximum values over all runs are shown below:
        i. F(2012)/F(MSY) = 0.46 (0.09-0.96)
        ii. SSB(2012)/SSB(MSY) = 2.46 (1.17-6.96)
        iii. SSB(2012)/SSB(0) = 0.52 (0.3-0.87)
        iv. MSY (1000 t) = 27.1K (16.8K-112.5K)
3. Priorities for future assessments include:
    - Migration rates were highly constrained in the model from different areas and this could be relaxed if studies indicate otherwise. Based on the results of Muths et. al. 2013, there may be reason to relax this as there is no genetic structure at the scale of the Indian Ocean.
    - Further consideration of all the CPUE series is warranted, but in particular, different methods to account for (and express the uncertainty associated with) the targeting shifts in the Japanese and Taiwanese fleets. The 2014 analysis used some clustering techniques that may account for that, and further examination of these approaches should be continued.
    - Examine the implications of the inconsistencies in the size frequency and logbook data, in terms of:
        - how to treat the size data in the model and whether higher weights need to be put on this information.
        - potential errors in the total catch time series
    - We recommend that Management Strategy Evaluation (MSE) should be used to develop manage procedures that are robust to the major uncertainties in the stock, with a primary emphasis on the SW region. As long as effort levels remain stable or continue to decline due to piracy (or other economic factors), there does not seem to be an urgent need for disruptive management action. This may create an effective time window where MSE could be pursued in preparation for the eventual return to historical fishing patterns, or the development of the coastal fleets.

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Young, J. and A. Drake. 2004. Age and growth of broadbill swordfish (Xiphius gladius)from Australian waters. Final report for project 2001/014, Fisheries Research Development Corporation, Canberra, Australia.

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Attachment 1. SS3 CONTROL.SS file template for the assessment. Each model assumption from Error! Reference source not found. **is created by the automated removal of flagged comment markers (e.g. for option 'io', the full 4 area Indian Ocean model, '# xxx io' is stripped out of the file).**

```
#V3.21d
#_data_and_control_files: DATA.SS // CONTROL.SS
#_SS-V3.21a-opt;_04/23/2011;_Stock_Synthesis_by_Richard_Methot_(NOAA)_using_ADMB
1  #_N_Growth_Patterns
1 #_N_Morphs_Within_GrowthPattern
#_Cond 1 #_Morph_between/within_stdev_ratio (no read if N_morphs=1)
#_Cond  1 #vector_Morphdist_(-1_in_first_val_gives_normal_approx)
#
# xxx io 4 #  number of recruitment assignments (overrides GP*area*seas parameter values)
# xxx io 0 # recruitment interaction requested
#GP seas area for each recruitment assignment
# xxx io   1 1 1
# xxx io   1 1 2
# xxx io   1 1 3
# xxx io   1 1 4

# xxx io 8 #_N_movement_definitions
# xxx io 0.6 # first age that moves (real age at begin of season, not integer)
# seas,GP,source_area,dest_area,minage,maxage
# xxx io  1 1 1 2 39 30
# xxx io  1 1 1 3 39 30
# xxx io  1 1 2 1 39 30
# xxx io  1 1 2 4 39 30
# xxx io  1 1 3 1 39 30
# xxx io  1 1 3 4 39 30
# xxx io  1 1 4 2 39 30
# xxx io  1 1 4 3 39 30
#
0 #_Nblock_Patterns
#_Cond 0 #_blocks_per_pattern
# begin and end years of blocks
#
0.5 #_fracfemale
0 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
  #_no additional input for selected M option; read 1P per morph
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=not implemented; 4=not implemented
0.01 #_Growth_Age_for_L1
999 #_Growth_Age_for_L2 (999 to use as Linf)
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0 #_CV_Growth_Pattern:  0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A); 4 logSD=F(A)
3 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity;
5=read fec and wt from wtatage.ss
#_Age_Maturity by growth pattern

 #TWN/Hawai'i Maturity 50% age 4
# xxx GtMf 0 0 0 0 0.02 0.1 0.5 0.9 0.98 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
# xxx GhMf 0 0 0.02 0.1 0.5 0.9 0.98 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 #CSIRO maturity 50% age 10
# xxx GaMf 0.00325603 0.007115515 0.014569273 0.028013449 0.050623862 0.085939643 0.136874216 0.20429726
0.285874625 0.376104793 0.467854808 0.554549562 0.631738337 0.69745447 0.751682329 0.795546622 0.830633963
0.858568952 0.880806505 0.898561132 0.912807328 0.912807328  0.912807328  0.912807328  0.912807328  0.912807328
0.912807328  0.912807328  0.912807328  0.912807328  0.912807328

1 #_First_Mature_Age
1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b; (4)eggs=a+b*L; (5)eggs=a+b*W
0 #_hermaphroditism option:  0=none; 1=age-specific fxn
1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
1 #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base parm bounds; 3=standard w/ no bound check)
#
#_growth_parms
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
# xxx GtMf  0.1 0.6 0.25 0.25 0 1 -8 0 0 0 0 0.5 0 0 # NatM_p_1_Fem_GP_1
# xxx GaMf  0.1 0.6 0.2 0.2 0 1 -8 0 0 0 0 0.5 0 0 # NatM_p_1_Fem_GP_1
# xxx GhMf  0.1 0.6 0.4 0.25 0 1 -8 0 0 0 0 0.5 0 0 # NatM_p_1_Fem_GP_1

# xxx GtMf  70 90 66.2     66.2 0 0.1 -2 0 0 0 0 0.5 0 0       # Wang IO L_at_Amin_Fem_GP_1
# xxx GtMf  310 340 274.9 274.9 0 0.1 -2 0 0 0 0 0.5 0 0   # Wang IO L_at_Amax_Fem_GP_1
# xxx GtMf  0.05 0.26 0.138 0.138 0 0.1 -3 0 0 0 0 0.5 0 0 # Wang IO VonBert_K_Fem_GP_1
```

```
# xxx GaMf  70 90 78.5 78.5 0 0.1 -2 0 0 0 0 0.5 0 0         # CSIRO L_at_Amin_Fem_GP_1_
# xxx GaMf  310 340 323.4 323.4 0 0.1 -2 0 0 0 0 0.5 0 0     # CSIRO L_at_Amax_Fem_GP_1_
# xxx GaMf  0.05 0.1 0.08148 0.08148 0 0.1 -3 0 0 0 0 0.5 0 0 # CSIRO VonBert_K_Fem_GP_1_

# xxx GhMf  70 90 72.6 72.6 0 0.1 -2 0 0 0 0 0.5 0 0         # NMFS L_at_Amin_Fem_GP_1_
# xxx GhMf  250 340 255.3 255.3 0 0.1 -2 0 0 0 0 0.5 0 0     # NMFS L_at_Amax_Fem_GP_1_
# xxx GhMf  0.24 0.26 0.246 0.246 0 0.1 -3 0 0 0 0 0.5 0 0   # NMFS VonBert_K_Fem_GP_1_

 0.05 0.25 0.15 0.15 0 0.15 -3 0 0 0 0 0 0.5 0 0 # CV_young_Fem_GP_1
 0.05 0.25 0.1 0.15 0 0.15 -3 0 0 0 0 0.5 0 0 # CV_old_Fem_GP_1

# xxx GtMf  0.1 0.6 0.25 0.25 0 1 -8 0 0 0 0 0 0.5 0 0 # NatM_p_1_Mal_GP_1
# xxx GaMf  0.1 0.6 0.2 0.2 0 1 -8 0 0 0 0 0.5 0 0 # NatM_p_1_Mal_GP_1
# xxx GhMf  0.1 0.6 0.4 0.25 0 1 -8 0 0 0 0 0.5 0 0 # NatM_p_1_Mal_GP_1

# xxx GtMf  70 90 72.1 72.1 0 0.1 -2 0 0 0 0 0 0.5 0 0 # L_at_Amin_Mal_GP_1
# xxx GtMf  230 280 234 234 0 0.1 -2 0 0 0 0 0.5 0 0 # L_at_Amax_Mal_GP_1
# xxx GtMf  0.26 0.28 0.169 0.169 0 0.1 -3 0 0 0 0 0.5 0 0 # VonBert_K_Mal_GP_1

# xxx GaMf   70 90 80.6 80.6 0 0.1 -2 0 0 0 0 0.5 0 0         # CSIRO L_at_Amin_Mal_GP_1_
# xxx GaMf   240 280 260.47 260.47 0 0.1 -2 0 0 0 0 0.5 0 0   # CSIRO L_at_Amax_Mal_GP_1_
# xxx GaMf   0.07 0.13 0.1096 0.1096 0 0.1 -3 0 0 0 0 0.5 0 0  # CSIRO VonBert_K_Mal_GP_1_

# xxx GhMf  70 90 77.1 77.1 0 0.1 -2 0 0 0 0 0.5 0 0         # NMFS L_at_Amin_Mal_GP_1_
# xxx GhMf  230 280 232.04 232.04 0 0.1 -2 0 0 0 0 0.5 0 0   # NMFS L_at_Amax_Mal_GP_1_
# xxx GhMf  0.26 0.28 0.271 0.271 0 0.1 -3 0 0 0 0 0.5 0 0   # NMFS VonBert_K_Mal_GP_1_

 0.05 0.25 0.15 0.15 0 0.15 -3 0 0 0 0 0 0.5 0 0 # CV_young_Mal_GP_1
  0.05 0.25 0.1 0.15 0 0.15 -3 0 0 0 0 0.5 0 0 # CV_old_Mal_GP_1
 -3 3 3.815e-006 3.815e-006 -1 99 -3 0 0 0 0 0 0.5 0 0 # Wtlen_1_Fem
 -3 4 3.188 3.188 -1 99 -3 0 0 0 0 0.5 0 0 # Wtlen_2_Fem
 35 73 55 55 -1 99 -3 0 0 0 0 0 0 0 0 # Mat50%_Fem
 -3 3 -0.25 -0.25 -1 99 -3 0 0 0 0 0 0 0 0 # Mat_slope_Fem
 -3 3 1 1 -1 99 -3 0 0 0 0 0 0 0 0 # Eggs/kg_inter_Fem
 -3 3 0 0 -1 99 -3 0 0 0 0 0 0 0 0 # Eggs/kg_slope_wt_Fem
 -3 3 3.815e-006 3.815e-006 -1 99 -3 0 0 0 0 0 0.5 0 0 # Wtlen_1_Mal
 -3 4 3.188 3.188 -1 99 -3 0 0 0 0 0.5 0 0 # Wtlen_2_Mal
 -8 8 0 1 -1 99 -3 0 0 0 0 0 0.5 0 0 # RecrDist_GP_1
 -8 8 0 1 -1 99 -4 0 0 0 0 0 0.5 0 0 # RecrDist_Area_1
# xxx io  -8 8 -0.509876 1 -1 99 4 0 1 1965 2008 0.9 0 0 # RecrDist_Area_2
# xxx io  -8 8 -0.295335 1 -1 99 4 0 1 1965 2008 0.9 0 0 # RecrDist_Area_3
# xxx io  -8 8 -0.187103 1 -1 99 4 0 1 1965 2008 0.9 0 0 # RecrDist_Area_4
 -8 8 0 1 -1 99 -7 0 0 0 0 0 0.5 0 0 # RecrDist_Seas_1
 1 1 1 1 -1 99 -3 0 0 0 0 0 0 0 0 # CohortGrowDev
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_1to_2
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_1to_2
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_1to_3
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_1to_3
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_2to_1
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_2to_1
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_2to_4
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_2to_4
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_3to_1
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_3to_1
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_3to_4
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_3to_4
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_4to_2
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_4to_2
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1_GP_1from_4to_3
# xxx io   -8 9 -7 -5 0 5 -9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1_GP_1from_4to_3
#
#_Cond 0  #custom_MG-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-environ parameters
#
#_Cond 0  #custom_MG-block_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-block parameters
#_Cond No MG parm trends
#
#_seasonal_effects_on_biology_parms
 0 0 0 0 0 0 0 0 0 0 #_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters
#
# xxx io 4 #_MGparm_Dev_Phase
#
```

```
#_Spawner-Recruitment
3 #_SR_function: 1=B-H_flattop; 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=Shepard_3Parm
#_LO HI INIT PRIOR PR_type SD PHASE
 7 18 8.42702 11 -1 100 3 # SR_R0
# xxx h55 0.2 1 0.55 0.55 1 0.1 -10 # SR_steep
# xxx h75 0.2 1 0.75 0.75 1 0.1 -10 # SR_steep
# xxx h95 0.2 1 0.95 0.95 1 0.1 -10 # SR_steep
# xxx r0 0 2 0.01 0.01 -1 0.8 -3 # SR_sigmaR
# xxx r2 0 2 0.2 0.2 -1 0.8 -3 # SR_sigmaR
# xxx r4 0 2 0.4 0.4 -1 0.8 -3 # SR_sigmaR
 -5 5 0.1 0 0 1 -3 # SR_envlink
 -5 5 0 0 0 1 -4 # SR_R1_offset
 0 0 0 0 -1 0 -99 # SR_autocorr
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
# xxx r4 1 #do_recdev:  0=none; 1=devvector; 2=simple deviations
# xxx r2 1 #do_recdev:  0=none; 1=devvector; 2=simple deviations
# xxx r0 0 #do_recdev:  0=none; 1=devvector; 2=simple deviations
1950 # first year of main recr_devs; early devs can preceed this era
2007 # last year of main recr_devs; forecast devs start in following year
6 #_recdev phase
1 # (0/1) to read 13 advanced options
 0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
 -5 #_recdev_early_phase
 5 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
 1 #_lambda for Fcast_recr_like occurring before endyr+1
 1970 #_last_early_yr_nobias_adj_in_MPD
 1971 #_first_yr_fullbias_adj_in_MPD
 2001 #_last_yr_fullbias_adj_in_MPD
 2002 #_first_recent_yr_nobias_adj_in_MPD
 1 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)
 0 #_period of cycles in recruitment (N parms read below)
 -6 #min rec_dev
 6 #max rec_dev
 0 #_read_recdevs
#_end of advanced SR options
#
#_placeholder for full parameter lines for recruitment cycles
# read specified recr devs
#_Yr Input_value
#
#
#Fishing Mortality info
0.2 # F ballpark for tuning early phases
2003 # F ballpark year (neg value to disable)
3 # F_Method:  1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
4 # max F or harvest rate, depends on F_Method
# no additional F input needed for Fmethod 1
# if Fmethod=2; read overall start F value; overall phase; N detailed inputs to read
# if Fmethod=3; read N iterations for tuning for Fmethod 3
2  # N iterations for tuning F in hybrid method (recommend 3 to 7)
#
#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
 0 1 0 0.01 0 99 -1 # InitF_1GI_NE
 0 1 0 0.01 0 99 -1 # InitF_2LL_NE
 0 1 0 0.01 0 99 -1 # InitF_3GI_NW
 0 1 0 0.01 0 99 -1 # InitF_4LL_NW
 0 1 0 0.01 0 99 -1 # InitF_5GI_SE
 0 1 0 0.01 0 99 -1 # InitF_6LL_SE
 0 1 0 0.01 0 99 -1 # InitF_7ALGI_SW
 0 1 0 0.01 0 99 -1 # InitF_8EUEL_SW
 0 1 0 0.01 0 99 -1 # InitF_9ISEL_SW
 0 1 0 0.01 0 99 -1 # InitF_10JPLL_SW
 0 1 0 0.01 0 99 -1 # InitF_11TWFL_SW
 0 1 0 0.01 0 99 -1 # InitF_12TWLL_SW
#
#_Q_setup
 # Q_type options:  <0=mirror, 0=median_float, 1=mean_float, 2=parameter, 3=parm_w_random_dev, 4=parm_w_randwalk,
5=mean_unbiased_float_assign_to_parm
 #_Den-dep  env-var  extra_se  Q_type
 0 0 0 2 # 1 GI_NE
 0 0 0 2 # 2 LL_NE
 0 0 0 2 # 3 GI_NW
 0 0 0 2 # 4 LL_NW
```

0 0 0 2 # 5 GI_SE
0 0 0 2 # 6 LL_SE
0 0 0 2 # 7 ALGI_SW
0 0 0 2 # 8 EUEL_SW
0 0 0 2 # 9 ISEL_SW
0 0 0 2 # 10 JPLL_SW
0 0 0 2 # 11 TWFL_SW
0 0 0 2 # 12 TWLL_SW

xxx io 0 0 0   2 # 13 UJPLL_NW
xxx io 0 0 0 -13 # 14 UJPLL_NE
xxx io 0 0 0 -13 # 15 UJPLL_SW
xxx io 0 0 0 -13 # 16 UJPLL_SE

xxx sw 0 0 0 2 # 13 UJPLL_NW
xxx sw 0 0 0 2 # 14 UJPLL_NE
xxx sw 0 0 0 2 # 15 UJPLL_SW
xxx sw 0 0 0 2 # 16 UJPLL_SE

0 0 0 2 # 17 UTWLL_NW
0 0 0 2 # 18 UTWLL_NE
0 0 0 2 # 19 UTWLL_SW
0 0 0 2 # 20 UTWLL_SE
0 0 0 2 # 21 URELL_SW
0 0 0 2 # 22 USPNLL_SW
xxx JS 0 0 0 2 # 23 UJ91p_SW

#
#_Cond 0 #_If q has random component, then 0=read one parm for each fleet with random q; 1=read a parm for each year of index
#_Q_parms(if_any)
LO HI INIT PRIOR PR_type SD PHASE
-10 10 -0.494066 0 0 99 -1 # Q_base_1_GI_NE
-10 10 -0.494066 0 0 99 -1 # Q_base_2_LL_NE
-10 10 -0.494066 0 0 99 -1 # Q_base_3_GI_NW
-10 10 -0.494066 0 0 99 -1 # Q_base_4_LL_NW
-10 10 -0.494066 0 0 99 -1 # Q_base_5_GI_SE
-10 10 -0.494066 0 0 99 -1 # Q_base_6_LL_SE
-10 10 -0.494066 0 0 99 -1 # Q_base_7_ALGI_SW
-10 10 -0.494066 0 0 99 -1 # Q_base_8_EUEL_SW
-10 10 -0.494066 0 0 99 -1 # Q_base_9_ISEL_SW
-10 10 -0.494066 0 0 99 -1 # Q_base_10_JPLL_SW
-10 10 -0.494066 0 0 99 -1 # Q_base_11_TWFL_SW
-10 10 -0.494066 0 0 99 -1 # Q_base_12_TWLL_SW
xxx io -20 10 -7.41213 0 0 99   1 # Q_base_13_UJPLL_NW #need to estimate this for SW version as well because of shared Q
xxx sw -20 10 -7.41213 0 0 99 -1 # Q_base_13_UJPLL_NW #need to estimate this for SW version as well because of shared Q
xxx sw -20 10 -7.41213 0 0 99 -1 # Q_base_14_UJPLL_NW #need to estimate this for SW version as well because of shared Q
xxx sw -20 10 -7.41213 0 0 99   1 # Q_base_15_UJPLL_NW #need to estimate this for SW version as well because of shared Q
xxx sw -20 10 -7.41213 0 0 99 -1 # Q_base_16_UJPLL_NW #need to estimate this for SW version as well because of shared Q

xxx io -20 10 -9.53595 0 0 99 1 # Q_base_17_UTWLL_NW
xxx sw -20 10 -9.53595 0 0 99 -1 # Q_base_17_UTWLL_NW
xxx io -20 10 -9.0215 0 0 99 1 # Q_base_18_UTWLL_NE
xxx sw -20 10 -9.0215 0 0 99 -1 # Q_base_18_UTWLL_NE
-20 10 -7.26104 0 0 99 1 # Q_base_19_UTWLL_SW
xxx io -20 10 -10.4321 0 0 99 1 # Q_base_20_UTWLL_SE
xxx sw -20 10 -10.4321 0 0 99 -1 # Q_base_20_UTWLL_SE
-20 10 -11.6308 0 0 99 1 # Q_base_21_URELL_SW
xxx io -20 10 -7.81646 0 0 99 1 # Q_base_22_UESPLL_SW
xxx sw -20 10 -7.81646 0 0 99 1 # Q_base_22_UESPLL_SW
xxx JS -20 10 -7.6308 0 0 99 1 # Q_base_23_UJ91p_SW

#
#_size_selex_types
#_Pattern Discard Male Special
24 0 0 0 # 1 GI_NE
24 0 0 0 # 2 LL_NE
5 0 0 1 # 3 GI_NW
5 0 0 2 # 4 LL_NW
5 0 0 1 # 5 GI_SE

5 0 0 2 # 6 LL_SE
5 0 0 1 # 7 ALGI_SW
5 0 0 2 # 8 EUEL_SW
5 0 0 2 # 9 ISEL_SW
5 0 0 2 # 10 JPLL_SW
5 0 0 2 # 11 TWFL_SW
5 0 0 2 # 12 TWLL_SW
5 0 0 2 # 13 UJPLL_NW
5 0 0 2 # 14 UJPLL_NE
5 0 0 2 # 15 UJPLL_SW
5 0 0 2 # 16 UJPLL_SE
5 0 0 2 # 17 UTWLL_NW
5 0 0 2 # 18 UTWLL_NE
5 0 0 2 # 19 UTWLL_SW
5 0 0 2 # 20 UTWLL_SE
5 0 0 2 # 21 URELL_SW
5 0 0 2 # 22 USPNLL_SW
xxx JS 5 0 0 2 # 23 UJ91p_SW
#
#_age_selex_types
#_Pattern ___ Male Special
10 0 0 0 # 1 GI_NE
10 0 0 0 # 2 LL_NE
10 0 0 0 # 3 GI_NW
10 0 0 0 # 4 LL_NW
10 0 0 0 # 5 GI_SE
10 0 0 0 # 6 LL_SE
10 0 0 0 # 7 ALGI_SW
10 0 0 0 # 8 EUEL_SW
10 0 0 0 # 9 ISEL_SW
10 0 0 0 # 10 JPLL_SW
10 0 0 0 # 11 TWFL_SW
10 0 0 0 # 12 TWLL_SW
10 0 0 0 # 13 UJPLL_NW
10 0 0 0 # 14 UJPLL_NE
10 0 0 0 # 15 UJPLL_SW
10 0 0 0 # 16 UJPLL_SE
10 0 0 0 # 17 UTWLL_NW
10 0 0 0 # 18 UTWLL_NE
10 0 0 0 # 19 UTWLL_SW
10 0 0 0 # 20 UTWLL_SE
10 0 0 0 # 21 URELL_SW
10 0 0 0 # 22 USPNLL_SW
xxx JS 10 0 0 0 # 23 UJ91p_SW

#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
xxx io 50 200 91.86 150 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_1P_1_GI_NE
xxx io -6 4 -1.061 -3 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_1P_2_GI_NE
xxx io -1 9 4.714 8.3 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_1P_3_GI_NE
xxx io -1 9 4.00 4 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_1P_4_GI_NE
xxx io -15 -5 -10 -1 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_5_GI_NE
xxx io -5 9 -0.730581 -1 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_1P_6_GI_NE

xxx sw 50 200 91.86 150 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_1_GI_NE
xxx sw -6 4 -1.061 -3 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_2_GI_NE
xxx sw -1 9 4.714 8.3 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_3_GI_NE
xxx sw -1 9 4.00 4 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_4_GI_NE
xxx sw -15 -5 -10 -1 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_5_GI_NE
xxx sw -5 9 -0.730581 -1 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_6_GI_NE

50 200 142.278 150 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_2P_1_LL_NE
-6 4 -0.316252 -3 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_2P_2_LL_NE
-1 9 6.97936 8.3 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_2P_3_LL_NE
-1 9 5.26149 4 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_2P_4_LL_NE
-15 -5 -10 -1 1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_2P_5_LL_NE
-5 9 -1.57659 -1 1 99 3 0 0 0 0 0.5 0 0 # SizeSel_2P_6_LL_NE
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_3P_1_GI_NW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_3P_2_GI_NW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_4P_1_LL_NW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_4P_2_LL_NW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_5P_1_GI_SE
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_5P_2_GI_SE
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_6P_1_LL_SE
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_6P_2_LL_SE
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_7P_1_ALGI_SW

-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_7P_2_ALGI_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_8P_1_EUEL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_8P_2_EUEL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_9P_1_ISEL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_9P_2_ISEL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_10P_1_JPLL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_10P_2_JPLL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_11P_1_TWFL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_11P_2_TWFL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_12P_1_TWLL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_12P_2_TWLL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_13P_1_UJPLL_NW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_13P_2_UJPLL_NW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_14P_1_UJPLL_NE
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_14P_2_UJPLL_NE
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_15P_1_UJPLL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_15P_2_UJPLL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_16P_1_UJPLL_SE
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_16P_2_UJPLL_SE
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_17P_1_UTWLL_NW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_17P_2_UTWLL_NW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_18P_1_UTWLL_NE
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_18P_2_UTWLL_NE
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_19P_1_UTWLL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_19P_2_UTWLL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_20P_1_UTWLL_SE
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_20P_2_UTWLL_SE
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_21P_1_URELL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_21P_2_URELL_SW
-5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_22P_1_USPNLL_SW
-5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_22P_2_USPNLL_SW
xxx JS -5 3 1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_22P_1_UJ91p_SW
xxx JS -5 3 -1 -4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_22P_2_UJ91p_SW

#_Cond 0 #_custom_sel-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no enviro fxns
#_Cond 0 #_custom_sel-blk_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no block usage
#_Cond No selex parm trends
#_Cond -4 # placeholder for selparm_Dev_Phase
#_Cond 0 #_env/block/dev_adjust_method (1=standard; 2=logistic trans to keep in base parm bounds; 3=standard w/ no bound check)
#
Tag loss and Tag reporting parameters go next
0 # TG_custom: 0=no read; 1=read if tags exist
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0 #_placeholder if no parameters
#
1 #_Variance_adjustments_to_input_values
#_fleet: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 # xxx JS 0 #_add_to_survey_CV
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 # xxx JS 0 #_add_to_discard_stddev
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 # xxx JS 0 #_add_to_bodywt_CV
xxx CL002 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 1 1 1 1 1 1 1 1 1 1 # xxx JS 1 #_mult_by_lencomp_N
xxx CL020 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 1 1 1 1 1 1 1 1 1 1 # xxx JS 1 #_mult_by_lencomp_N
xxx CL200 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1 1 1 1 1 1 1 1 1 1 # xxx JS 1 #_mult_by_lencomp_N
xxx CLb200 1. 1. 1. 1. 1. 1. 1. 0.1 0.1 1. 1. 1. 1 1 1 1 1 1 1 1 1 1 # xxx JS 1 #_mult_by_lencomp_N
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 # xxx JS 1 #_mult_by_agecomp_N
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 # xxx JS 1 #_mult_by_size-at-age_N
#
4 #_maxlambdaphase
1 #_sd_offset
#
44 # number of changes to make to default Lambdas (default value is 1.0)
Like_comp codes: 1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch;
9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp; 16=Tag-negbin
lambdas like_comp fleet/survey phase value sizefreq_method
xxx io 1 13 1 1 1
xxx io 1 14 1 1 1
xxx io 1 15 1 1 1
xxx io 1 16 1 1 1
xxx io 1 17 1 1 1
xxx io 1 18 1 1 1
xxx io 1 19 1 1 1
xxx io 1 20 1 1 1
xxx io 1 21 1 1 1

```
# xxx io   1 22 1 1 1
# xxx sw   1 13 1 0 1
# xxx sw   1 14 1 0 1
# xxx sw   1 15 1  1 1
# xxx sw   1 16 1 0 1
# xxx sw   1 17 1 0 1
# xxx sw   1 18 1 0 1
# xxx sw   1 19 1 1  1
# xxx sw   1 20 1 0 1
# xxx sw   1 21 1  1 1
# xxx sw   1 22 1  1 1
 4 1 1 0.1 1
 4 2 1 0.1 1
 4 3 1 0.1 1
 4 4 1 0.1 1
 4 5 1 0.1 1
 4 6 1 0.1 1
 4 7 1 0.1 1
 4 8 1 0.1 1
 4 9 1 0.1 1
 4 10 1 0.1 1
 4 11 1 0.1 1
 4 12 1 0.1 1

# JS option left to default of UJ91p_SW wt=1; so equal to NT

# xxx io   # xxx A1  1 13 4 1 1
# xxx io   # xxx A1  1 14 4 1 1
# xxx io   # xxx A1  1 15 4 1 1
# xxx io   # xxx A1  1 16 4 1 1
# xxx io   # xxx A1  1 17 4 1 1
# xxx io   # xxx A1  1 18 4 1 1
# xxx io   # xxx A1  1 19 4 1 1
# xxx io   # xxx A1  1 20 4 1 1
# xxx io   # xxx A1  1 21 4 1 1
# xxx io   # xxx A1  1 22 4 1 1

# xxx sw   # xxx A1  1 13 4 0 1
# xxx sw   # xxx A1  1 14 4 0 1
# xxx sw   # xxx A1  1 15 4  1 1
# xxx sw   # xxx A1  1 16 4 0 1
# xxx sw   # xxx A1  1 17 4 0 1
# xxx sw   # xxx A1  1 18 4 0 1
# xxx sw   # xxx A1  1 19 4  1 1
# xxx sw   # xxx A1  1 20 4 0 1
# xxx sw   # xxx A1  1 21 4  1 1
# xxx sw   # xxx A1  1 22 4  1 1

# xxx sw   # xxx J2  1 13 4 0 1
# xxx sw   # xxx J2  1 14 4 0 1
# xxx sw   # xxx J2  1 15 4  0.25 1
# xxx sw   # xxx J2  1 16 4 0 1
# xxx sw   # xxx J2  1 17 4 0 1
# xxx sw   # xxx J2  1 18 4 0 1
# xxx sw   # xxx J2  1 19 4  1 1
# xxx sw   # xxx J2  1 20 4 0 1
# xxx sw   # xxx J2  1 21 4  1 1
# xxx sw   # xxx J2  1 22 4  1 1

# xxx io   # xxx NT  1 13 4 1 1
# xxx io   # xxx NT  1 14 4 1 1
# xxx io   # xxx NT  1 15 4 1 1
# xxx io   # xxx NT  1 16 4 1 1
# xxx io   # xxx NT  1 17 4 0.001 1
# xxx io   # xxx NT  1 18 4 0.001 1
# xxx io   # xxx NT  1 19 4 0.001 1
# xxx io   # xxx NT  1 20 4 0.001 1
# xxx io   # xxx NT  1 21 4 1 1
# xxx io   # xxx NT  1 22 4 1 1

# xxx sw   # xxx NT  1 13 4 0 1
# xxx sw   # xxx NT  1 14 4 0 1
# xxx sw   # xxx NT  1 15 4  1 1
# xxx sw   # xxx NT  1 16 4 0 1
# xxx sw   # xxx NT  1 17 4 0 1
```

xxx sw # xxx NT 1 18 4 0 1
xxx sw # xxx NT 1 19 4 0.001 1
xxx sw # xxx NT 1 20 4 0 1
xxx sw # xxx NT 1 21 4 1 1
xxx sw # xxx NT 1 22 4 1 1

xxx io # xxx J1 1 13 4 1 1
xxx io # xxx J1 1 14 4 1 1
xxx io # xxx J1 1 15 4 1 1
xxx io # xxx J1 1 16 4 1 1
xxx io # xxx J1 1 17 4 0.001 1
xxx io # xxx J1 1 18 4 0.001 1
xxx io # xxx J1 1 19 4 0.001 1
xxx io # xxx J1 1 20 4 0.001 1
xxx io # xxx J1 1 21 4 0.001 1
xxx io # xxx J1 1 22 4 0.001 1

xxx sw # xxx J1 1 13 4 0 1
xxx sw # xxx J1 1 14 4 0 1
xxx sw # xxx J1 1 15 4 1 1
xxx sw # xxx J1 1 16 4 0 1
xxx sw # xxx J1 1 17 4 0 1
xxx sw # xxx J1 1 18 4 0 1
xxx sw # xxx J1 1 19 4 0.001 1
xxx sw # xxx J1 1 20 4 0 1
xxx sw # xxx J1 1 21 4 0.001 1
xxx sw # xxx J1 1 22 4 0.001 1

xxx io # xxx JS 1 13 4 1 1
xxx io # xxx JS 1 14 4 1 1
xxx io # xxx JS 1 15 4 1 1
xxx io # xxx JS 1 16 4 1 1
xxx io # xxx JS 1 17 4 0.001 1
xxx io # xxx JS 1 18 4 0.001 1
xxx io # xxx JS 1 19 4 0.001 1
xxx io # xxx JS 1 20 4 0.001 1
xxx io # xxx JS 1 21 4 1 1
xxx io # xxx JS 1 22 4 1 1

xxx sw # xxx JS 1 13 4 0 1
xxx sw # xxx JS 1 14 4 0 1
xxx sw # xxx JS 1 15 4 1 1
xxx sw # xxx JS 1 16 4 0 1
xxx sw # xxx JS 1 17 4 0 1
xxx sw # xxx JS 1 18 4 0 1
xxx sw # xxx JS 1 19 4 0.001 1
xxx sw # xxx JS 1 20 4 0 1
xxx sw # xxx JS 1 21 4 1 1
xxx sw # xxx JS 1 22 4 1 1

4 1 4 1 1
4 2 4 1 1
4 3 4 1 1
4 4 4 1 1
4 5 4 1 1
4 6 4 1 1
4 7 4 1 1
4 8 4 1 1
4 9 4 1 1
4 10 4 1 1
4 11 4 1 1
4 12 4 1 1

#
0 # (0/1) read specs for more stddev reporting
0 1 -1 5 1 5 1 -1 5 # placeholder for selex type, len/age, year, N selex bins, Growth pattern, N growth ages, NatAge_area(-1 for all), NatAge_yr, N Natages
placeholder for vector of selex bins to be reported
placeholder for vector of growth ages to be reported
placeholder for vector of NatAges ages to be reported
999