A Spatially-Structured Stock Synthesis Assessment of the Indian Ocean Swordfish Fishery 1950-2008, including Special Emphasis on the SW Region

Dale Kolody
IOTC Secretariat
Dale.Kolody@iotc.org

Summary

An update of the 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. While the model does produce stock status estimates for management, at this time it is most useful as an exploratory tool for illustrating the conflicts among the different sources of data and biological assumptions. Given the large uncertainties in the Indian Ocean swordfish fishery (i.e. relative abundance indices derived from widespread commercial fleets with shifting effort distributions and targeting practices, unknown stock structure, poorly quantified growth rates and natural mortality, uninformative catch-at-size distributions), there is little justification for selecting a 'best' model. This platform is considered to be most useful for prioritizing avenues for reducing the uncertainty, and ideally, to help identify management strategies that are robust to the uncertainties. Given time constraints in 2010, few models could be fit during the WPB. Core assumptions of most models included:

- The population is age- and sex-structured, iterated on a quarterly time-step from 1952-2008.
- The population is split among 4 fishing areas. It is assumed that there is a common spawning ground, but fish are only vulnerable to harvesting in the 4 fishing areas, (i.e. this might be described as foraging grounds site fidelity, such that the model can describe differential depletion by area and it is assumed that there is limited mixing among areas).
- Recruitment follows a Beverton-Holt relationship, with lognormal deviations, and a proportional distribution of recruits among areas that remains constant over time (i.e. all areas have identical relative recruitment time series, but they differ in magnitude).
- There are 24 fleets, each assigned to a single area (only two selectivity functions were estimated this year, so many of the fleets could be aggregated).
- There are 2 (pseudo-) length-based selectivity functions estimated: i) longline and ii) gillnet/other. A domed, 'double normal' shape was assumed for both.
- In most cases, Japanese CPUE catchability was shared among areas (the CPUE series for each area was first scaled in proportion to the surface area of each region to convert relative density to relative abundance among areas).
- The objective function includes lognormal observation errors on 10 CPUE-based relative abundance indices, robust multinomial terms for length composition data from 18 fleets, lognormal recruitment deviations, plus a very diffuse prior for each of the estimated parameters.
- In most cases, 79 free parameters were estimated: recruitment deviations, selectivity functions, catchability coefficients, mean virgin recruitment, and the spatial pattern of recruitment. The following parameters were fixed: variances/weightings on recruitment deviations and CPUE errors, life history parameters describing growth, M, maturity schedule. In some cases stock recruitment steepness was estimated.

The results were sensitive to alternative life history assumptions (growth rate, M, maturity, and stock-recruit steepness) and relative weighting of different data sources in the objective function. The model fit many sources of data reasonably well, but did not have sufficient flexibility to resolve some

important conflicts. Given the large uncertainties and the potential interactions among them, this was not considered to be a comprehensive exploration of the plausible parameter space. However, the aggregate Indian Ocean models were generally optimistic in terms of current stock status, and did not suggest the need for urgent management action (e.g. for all Maximum Posterior Density, MPD, estimates: i.e. for 2008, SSB ≥ 1.73 BMSY, SSB ≥ 0.39 SSB0 and F ≤ 0.78 FMSY). This status is consistent with expectations given the large recent declines in catch and effort (primarily due to reduced activity of the Taiwanese fleet).

However, an important longstanding issue remains unresolved. The prime motivation for developing the SS3 model in 2009 was to increase the resolution of spatial processes, so that the differential and possibly elevated depletion in the SW Indian Ocean could be more explicitly described. During the WPB 2010, the model specifications explored were not very successful at fitting the sharp CPUE declines in the SW region. Subsequent to the WPB, additional effort was spent trying to resolve the problem. Two approaches were employed:

1. The 4 area structure was maintained, but the flexibility to fit the SW was increased by relaxing the shared catchability constraint and/or increasing the relative weighting of the CPUE series in the SW. It was found that the substantial CPUE decline estimated by the Reunion fleet in the mid-1990s can be described reasonably well, and this does not have a serious adverse effect on the fit to the other data sources or the stock status inferences. However, the very steep decline in the SW Japanese CPUE in the early 1990s could not be described without adversely affecting the fit to the other model areas (and unresolved numerical problems were encountered).
2. The spatial structure was reduced to a single area of the SW (with 5 fleets and 3 CPUE series) under the assumption that this may represent a reasonably distinct sub-population (analogous to the approach used with the SCAM assessment, IOTC-2010-WPB-14). Important differences in the SS3 approach relative to SCAM included fitting to the size composition data, and estimation of the selectivity functions (i.e. SCAM imposed a logistic selectivity function and did not explicitly fit the size data).

The latter models were able to fit the SW CPUE series reasonably well, but not all series fit simultaneously, because the Japanese and Taiwanese CPUE trends strongly conflict in recent years. The different SS3 SW sub-region models supported very different stock status estimates (e.g. 2008 SSB estimated to range from <1% to 43% of virgin levels), depending on the interactions among the assumptions and data weighting. There are serious doubts about the main data series: i) the JPN and TWN fleets are known to shift species targeting historically, such that the conflicting series are sensitive to the analytical approach used to standardize the CPUE, and ii) the size composition data do not show strong evidence of recruitment deviations and very high depletion, but there are also reasons for doubting the separability assumptions given the historical targeting changes. The SCAM stock status estimates were similar to the central SS3 estimates, and both sets of models shared the common feature that the steep decline in Japanese CPUE in the 1990s could only be explained by the combined effect of fishing mortality and large recruitment anomalies (i.e. a series of positive recruitment deviations followed by a series of negative deviations). While large uncertainties remain, there is some compelling evidence that the most pessimistic models are not credible. Specifically, the Spanish and Reunion fleets are believed to have maintained reasonably consistent targeting practices, and the nominal CPUE and size composition data over recent years seems to be very stable for these fleets. Unfortunately much of this data was not available in the appropriate format to include in the assessments.

Several avenues for further research are recommended.

Introduction

"The purpose of models is not to fit the data but to sharpen the questions." -Samuel Karlin

Over the past couple years, Indian Ocean swordfish stock assessment has been conducted with a range of models, ranging from simple production models, to highly disaggregated integrated analyses (WPB 2009). It has generally been recognized that this is a useful approach, as it provides a range of perspectives on a highly uncertain fishery system. This paper was intended as a continuation of the

‘Stock Synthesis 3’ (SS3) exploratory modelling exercise that began in 2009 (IOTC-2009-WPB-10-revised). The main feature that this approach provided that was not included in any of the other models, was the spatial disaggregation, and the potential to describe differential (localized) depletion within the Indian Ocean. This was motivated by the ongoing concern for the SW region, which seems to be more highly depleted than the other regions on the basis of CPUE analyses. In recent years, CPUE analyses have been based on a 4 area structure (Figure 1), and this provided a reasonable basis on which to begin exploring spatial issues in the assessment.

There are a range of possible ways in which spatial structure can be relevant in an assessment. If the population has a single spawning stock with rapid mixing, spatial structure may not be important and it probably makes little difference where the fishery operates (e.g. Figure 2a). In contrast, if there are several discreet stocks, it is possible to seriously overfish one stock under the mistaken assumption that fish from adjacent areas will rapidly diffuse into the region of the fishery (e.g. Figure 2b). There are potentially other intermediate scenarios, where there is effectively one spawning population, but site fidelity on foraging grounds (e.g. Figure 2c), or there could be multiple discreet spawning populations that are all vulnerable on shared foraging grounds (not shown). It is hoped that tagging studies and genetic analyses from the IOSSS project will help to refine the spatial assumptions in the Indian Ocean swordfish population when results become available in 2011-12 (WPB 2010).

Two approaches were used to examine the spatial issues in 2010. First, a 4 area population structure as represented in Figure 2c was explored (during the 2010 WPB). It was hoped that this would be more successful than in 2009, primarily because of a targeted effort to revisit the CPUE analyses. The following main differences were invoked in 2010:

- One additional year of data for most fleets.
- New CPUE standardization analyses have been conducted for the Taiwanese, Japanese, and Reunion fleets.
- The Seychelles semi-industrial fleet CPUE series was included (though in an exploratory fashion, with an uninformative weighting).
- Some of the historical size composition data have been substantially revised from the Taiwanese fleet for recent years.
- Life history parameters from recent Taiwanese sampling in the northern Indian Ocean have been explored (Wang et al. 2010).

However, the poor fit to the SW CPUE could not be adequately explored during the WPB. Additional models were fit subsequent to the WPB, and it was concluded that the disaggregated model covering the whole Indian Ocean did not have adequate flexibility to fit all of the data sources. Initial exploration of the SW region as an independent stock was conducted along the lines of the SCAM assessment that was also introduced in 2010 (Martell 2010). The main difference from the SCAM approach was the inclusion of the size composition data, and estimation of selectivity in the SS3 models. These latter results are belatedly described as a reference for the assessment activities to be undertaken at the 2011 WPB, and key model files are archived with the IOTC Secretariat.

Methods

Data

There are many different fleets catching swordfish in the Indian Ocean, with vastly different gear types and levels of data quality (Herrera and Pierre 2010). The SS3 assessment uses the 24 fleet disaggregation provided by the IOTC Secretariat as described in Table 1 (the spatial disaggregation used by the secretariat was provided in response to the WPB request). Industrial longline fleets with reasonable reporting standards take the majority of the catch, though substantial numbers of swordfish are taken in artisanal and industrial net fisheries as well. The main fisheries data are briefly described below, while additional biological data are described in the section on model assumptions.

Total catch in mass

Catch by quarter area and fleet is shown in Figure 3, with total catches by year and area in Figure 4. There are some concerns about the total catch records for some of the fleets. 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.

This data is fundamental to almost every stock assessment, and it is almost pointless to try to quantify the impact of a fishery on the stock without good estimates of the magnitude of the catches. In 2010, the secretariat made a first attempt to look at the potential magnitude of catch uncertainty using some alternative assumptions (WPB 2010), and the initial results did not suggest any serious biases in the time series.

Relative abundance indices

Standardized commercial CPUE series provide the relative abundance indices for this assessment. In 2010, a 'core area' approach was used in which attempts were made to identify the regions in which the Japanese (JPN) and Taiwanese (TWN) fleets operated the most consistently over time. These regions are shown in Figure 5 along with the areas used for the Reunion (REU) and Seychelles (SEZ) CPUE analyses. It is assumed that each of these core areas provides an index of abundance that is relevant for the swordfish population of the broader region (i.e. NW, NE, SW or SE). The hope was that focussing on core areas would i) reduce the need for relatively fine-scale spatial effects in the standardization model to account for shifting effort distributions (i.e. previous analyses assumed that large and inconsistently fished areas of the Indian Ocean were homogenous), and ii) if the areas represent a fishery with consistent targeting practices, this may reduce the effect of other operational targeting issues that cannot be quantified from the available logbook data. However, in 2010, there still appear to be large inconsistencies among the different CPUE series that are assumed to index the same population. It has also been noted that the core area approach might not be very effective if there is a large degree of variability in the spatial distribution of the species among years. However, this criticism is applicable to other standardization approaches in the Indian Ocean as well, because the effort distribution has always been patchy and variable for the JPN and TWN fleets, such that it would rarely be possible to describe spatial variability in the population regardless of the area defined for analysis.

JPN CPUE series were provided by Nishida and Wang (2010) for the period 1980-2008 and TWN series by Wang and Nishida (2010a) for the period 1995-2008. Standardized CPUE series from REU 1994-2000 (Kolody et al. 2010a) and the SEZ semi-industrial fleet 1996-2008 (Kolody et al. 2010b) were also included. A number of features are immediately evident from these time series that have implications for the assessment (Figure 6):

- In most areas, the CPUE series are very noisy, on a time-scale that is not consistent with swordfish recruitment and mortality.
- 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.
- CPUE in the SW region appears to be well-behaved over the period of the late 1990s, with JPN, TWN and REU all showing a very similar trend. However, the JPN and TWN trends strongly conflict over the last few years, with JPN steeply increasing, and TWN steeply decreasing. The unstandardized REU and Spanish CPUE series over the last few years show a relatively stable or slightly declining trend over this period (not included in the assessment, but visible in WPB 2010).
- The SW JPN series shows a very steep decline between 1990-91, which predates the very large catches in the SW region. Further doubt about this series is raised because the timing of this CPUE drop is sensitive to the CPUE standardization analysis. Figure 7 compares the standardized JPN SW CPUE from the 2009 and 2010 analyses. In 2009, the drop was observed between 1994-95, which was then regarded as suspicious because of known operational changes (i.e. the rapid shift between rope and monofilament mainlines). Something is happening in the SW JPN fleet in the early 1990s that is causing a very steep decline in swordfish CPUE, but it is probably only partly attributable to changing swordfish abundance.
- The final (2008) CPUE observation for the TWN fleet is very low, and inconsistent with the other series. This observation needs to be investigated, and may simply be an artefact of a very small amount of effort. However, this point was retained for all the SS3 models discussed here.

Size composition data

Size data are available for 18 of the 24 fleets. However, size composition data quality is often poor, with small and non-random sampling for many fleets, and changes in coverage over time (Herrera and

Pierre 2010). The size data from Japan and Taiwan are provided to the secretariat at a very coarse resolution 10 degrees lat X 20 degrees lon. This creates an additional problem in that the secretariat has to artificially partition these observations to fit the WPB spatial structure (and should be easily avoided).

Time series of mean size by fleet can be seen in the example model results of Figure 11. Notably, some fleets operating in the same sub-region appear to have somewhat differing trends in mean size.

Software

The model was implemented with Stock synthesis SS V3.10 (Methot 2000, 2009). Typical function minimization of the fully disaggregated model on a 3.0 GHz personal computer requires about 10 minutes. A number of simplifications and aggregations could presumably reduce the minimization time by a factor of 10 or more, without significant loss to the stock status inferences. However, given the current exploratory manner in which the model is being used, 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 verbally in the following sections, while Methot (2000, 2009) provides the equations for the population dynamics and likelihood functions. Attachment 1 is the SS3 '.ctl' specification file for model IO-7, which includes additional information on secondary elements of model formulation which may be omitted in the description below.

Alternative model specifications are described in Table 2 for the aggregate Indian Ocean assessment, and Table 3 for the SW sub-region assessment. Note that in these tables, the weighting factors refer to a multiplier that is applied to the indicated likelihood term, such that a lognormal likelihood with σ_1 = 0.2 combined with a down-weighting factor λ = 0.01 is equivalent to the original likelihood with σ_2 = sqrt(σ_1^2/ λ) = 2.

Time Period

The model was run from 1950-2008 using a quarterly time-step. In the current implementation, there is no strong reason for maintaining the quarterly time-step, as the CPUE indices were assumed to be annual indices, however, the quarterly time-step does potentially allow the exploration of seasonal migration dynamics at some point in the future (including implications for seasonal size changes).

Spatial Structure

Two different spatial structures were explored i) the aggregate Indian Ocean population (Figure 1), and ii) the SW Indian Ocean sub-region on its own.

Aggregate Indian Ocean Model
The model is disaggregated into 4 areas corresponding to those used in the JPN and TWN catch rate standardization analyses (Figure 1). Some evidence suggests that there may be genetic distinction within the IO (Muths et al. 2009), and this is the subject of ongoing investigation of the IOSSS project led by IFREMER, Reunion (WPB 2010). Given the vast size of the Indian Ocean, and the migration rate inferences that have been made from tagging studies (particularly in other oceans), it seems unlikely that there would be rapid mixing processes across the whole basin, even if the population was genetically homogeneous. As such, localized overfishing could result in negative local consequences even if the overall stock is not overfished and there is a low risk of declining genetic diversity. The 4 area structure seems reasonably consistent with spawning area hypotheses (e.g. Poisson and Fauvel 2009), and also conveniently partitions most of the national fleets.

South-West Sub-Region Model
The SW models only included catch and size data from 6 fleets and 3 CPUE series (JPN, TWN and REU). There was no spatial structure within the region. For expedience (and consistency in fleet numbering, etc.), the SW version of the model was specified with a minimal reconfiguration of the 4 area model specification files. All fleets were maintained, but the population was aggregated into a

single area, catches from outside of the SW region were reduced by a factor of 0.001 (total non-SW catch represented <0.0025 of the SW catch), and all non-SW likelihood terms were down-weighted by a factor of 1E-7. This is not the ideal way to produce alternative configurations since it maintains a large unnecessary computational overhead. However, the greater time issue in the use of SS3 can be the initial specification of the model files, and this approach provided a simple solution.

Migration Dynamics

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 and Chris Wilcox, CSIRO, Australia, pers. Comm.).

However, we can indirectly infer that there are probably some relatively large seasonal migrations. Swordfish can be caught at least as far south as 45S, 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 reported spawning season is also 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.

SS3 can be used to estimate movement rates, however, these estimates are probably of little value in the absence of tagging data. In all of the models used in 2010, migration rates were fixed at very low levels (<< 1% per year), which essentially creates 4 populations except for the shared spawning and recruitment dynamics. There was no spatial structure within the SW sub-region models.

Fishery Definitions

Twenty four fleets were defined, corresponding to the data aggregation units supplied by the IOTC Secretariat (Table 2). Each fleet resides in a single area only. If the same nation operates in more than one region, these operations are described as a separate fleet. The preliminary work in 2009 suggested that most fleets could probably be aggregated, since the size composition data are either missing, poor, or similar for most longline fleets. The advantage to maintaining this level of disaggregation relates to the potential future need to explore the characteristics of the individual fleets. There are many longline fleets with similar selectivity, but the nature of the fishery and sampling programmes is vastly different.

Age Structure

The swordfish population is age-structured with cohorts of 0-40+ years. The plus-group was made deliberately large to allow for current and future uncertainties in growth rates and M.

Sex Structure

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

- Growth curves differ by sex
- Spatial distributions often differ by sex (i.e. with large females disproportionately found in cooler temperate waters)
- Selectivity may differ by sex due to the differing spatial distributions, but there also may be direct size biases (e.g. commercial fishers report that large fish may be less vulnerable to circle hooks).
- Natural mortality may also be sex-specific, but no distinction was made in the 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 expansion.

Age and Size

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 (Figure 8). As in 2009, alternative growth curves were explored to bracket two cases that might be plausible given the scarcity of age validation data for swordfish:

- CSIRO estimates derived from South-East Indian Ocean fin rays samples (Young and Drake 2004).
- NMFS estimates derived from Hawaiian samples (DeMartini et al. 2007). Visually, it appears that the NMFS growth curve cannot adequately account for the largest fish in the Indian Ocean very well (but it still might accurately reflect the high growth rates for young individuals).
- In 2010, a third growth curve approximately corresponding to that described in Wang et al. (2010), was employed, because it is derived from a large number of samples in the Taiwanese fishery, is intermediate between CSIRO and NMFS, and facilitated a comparison of results across modelling approaches. The growth curve used here was an approximation because it was only the von Bertalanffy K parameters that were adopted (other parameters corresponded to the CSIRO growth curve).

The uncertainty in age estimation is described in Young et al. (2008). The biological characteristics of the Hawaiian swordfish may differ considerably from the Indian Ocean, however, if the NMFS age estimation method is more accurate than the CSIRO method, then the Hawaiian growth curve is probably preferable. e.g. Young et al. (2008) illustrate that the Hawai'ian growth curve is probably very similar to the East-coast Australian growth curve that would have been estimated if the NMFS fin-spine reading method had been employed.

Length-at-age was assumed to be normally distributed around the mean length-at-age relationship.

Maturity and Spawning Stock Biomass

SS3 can use age-specific vectors of female maturity or fecundity for biomass spawning calculations. While a number of studies quantify the relationship between size and maturity, the uncertainty of age estimation that undermines the growth relationships also undermines the maturity/fecundity by age relationship. Three relationships were assumed, one for each growth curve:

- 50% maturity ~age 10, corresponding to the CSIRO study (mostly based on SW Pacific samples).
- 50% maturity ~age 4, logistic function, corresponding with one of the youngest age at maturity schedules used in swordfish assessment, and applied to the NMFS growth curve.
- 50% maturity ~age 6, logistic function, applied to the Taiwanese growth.

Natural Mortality

For the slow growth curve scenarios, M was assumed to be 0.2, constant across all ages. For the fast growth curve scenarios, M was assumed to be 0.4. These values resemble those used in Kolody et al. (2008), in which several age-specific, and growth-curve-specific M vectors were tested (the means were roughly consistent with the Pauly relationship which estimates M as a function of growth curve K and temperature preferences). The value of M=0.25 was adopted for the Taiwanese growth curve, to maintain consistency with Wang and Nishida (2010b).

Selectivity

In 2009, results were found to be insensitive to selectivity assumptions (age-based vs: pseudo-length-based; 18 functions vs: 3 functions). A single option was employed in 2010: two different size-based "double normal" selectivity curves were estimated, one for longline fleets, and one for the gillnet (and 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).

Catchability

Catchability was assumed to be constant over time for all CPUE series. In most cases, catchability was shared among areas for all of the Japanese fleets, and estimated independently for all other fleets. The shared catchability means that relative abundance is assumed to be maintained across regions, (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 is why the area-specific CPUE series (which measure density) need to be scaled by the relative area which the series is believed to describe.

The shared catchability constraint is often useful for preventing bizarre localized behaviour in spatial models. However, some strong untested assumptions are usually required to produce the scaling factors (e.g. in this case, density across the whole SE region is assumed to be equivalent to that derived from the little consistently-fished area off the west coast of Australia). 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 albacore fishery, and the implications of these types of assumptions warrant further investigation. Note that there is an identical (or at least equally strong and untested) assumption involved in creating a single abundance index for the whole Indian Ocean as applied in the aggregated models. The 2009 SS3 assessment examined the implicit catchability assumptions that resulted from the Japanese and Taiwanese CPUE analyses, and it was clear that the series from the two fleets implied very different relative abundance among areas.

A few of the aggregate IO models fit after the WPB (io-9 to io-13) relaxed the shared catchability constraint for the SW region, but maintained it in the 3 other regions. This seemed to make very little difference to the overall dynamics. Shared catchability was not relevant for the single region SW models.

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 of iterations to approximate instantaneous F from the Baranov catch equation (4 iterations were used for the aggregate IO model, 7 for the SW sub-region model). It has been observed that SS3 has a reputation for not using enough iterations to properly extract the catch when fishing mortality is very high (Steven Martell, UBC, Canada, pers. Comm.), but this was not tested.

Catch-at-Size sampling characteristics

Some of the swordfish sample sizes are very large for some fleets. In the context of the current separable models, this might cause a misleading overfitting to the size composition data 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 fish was discarded.
- The input sample sizes (i.e. assumed number of purely random samples in the likelihood terms) were reduced by a factor of 10. Any samples larger than 1000 at this point were truncated at 1000.
- A somewhat arbitrary (and relatively large) constant (1%) was added to each of the predicted and observed length bins (6 cm intervals) to reduce the influence of outliers.

CPUE characteristics

The annual indices were assumed to correspond to abundance in quarter 1 (the implications of abundance changes within a year are negligible relative to the noise in the CPUE series). The standardized CPUE was assumed to be directly proportional to selected abundance (in numbers). The default assumption was that the CPUE series was unrealistically informative (SD(log) = 0.1).

Essentially this was done to reflect 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). In most cases, particularly for the SW region, some series were strongly down-weighted, to reflect the possibility that one extreme or the other might be more likely than the average of two conflicting series (e.g. Schnute and Hilborn 1993).

Stock Recruitment Relationship

A Beverton-Holt stock recruitment relationship was assumed, in most cases with a fixed steepness of 0.9 or 0.7. It was assumed that spawning biomass is equal to the mass of the mature females. In SS3, spawning biomass cannot be spatially disaggregated, so for stock-recruitment purposes, the biomass is the sum of all areas. Area-specific parameters were estimated to distribute the recruitment among regions, and these proportions are constant among years (i.e. no area-specific recruitment deviations can be estimated using the current version of SS3).

Deviations from the stock-recruitment relationship were assumed to follow a lognormal distribution, with SD(log) = 0.2 or 0.6. The lower value (which is probably unrealistic) was assumed to prevent the model from overfitting the large degree of noise in the CPUE series, and the small catch-at-size samples. The higher value was adopted in attempts to allow the model additional freedom to fit the steep CPUE declines in the SW region.

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, 3 for the SW sub-region model)
- Length frequencies – multinomial distribution (downweighted sample sizes by a factor of 10, with a maximum of 1000, and 1% added to each 6 cm bin)
- Recruitment deviates (lognormal) from the stock-recruitment relationship

Prior distributions and Penalties:

- 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. symmetric beta distributions with SD = 99-100, attachment 1). The prior on steepness may have been weakly informative (mode = 0.9, SD = 10), in the few models in which it was invoked, but the intent in estimating it was primarily for purposes of qualitative comparison with the SCAM results.

- 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 official number of estimated parameters registered by SS3 was 100-102 (depending if steepness and Japanese catachability in the SW region were estimated). However, many of these parameters have no real influence on the model, (i.e. forecast recruitment deviates; catchabilities for extremely down-weighted CPUE were fit for plotting purposes, but were not informative in the model). The informative parameters included:

- Catchability for the informative CPUE series (max. 7 for IO, 3 for SW)
- Selectivity parameters – 5 for each double-normal function (10 for IO, 5 for SW)
- Virgin recruitment (1)
- Stock-Recruitment steepness (0-1)

- Annual recruitment deviations from the stock recruitment relationship (57)
- Recruitment distribution by area (3 for aggregate IO, 0 for SW)

Uncertainty Quantification

At this time, no attempt was made to quantify the statistical uncertainty associated with any of the models, and only the Maximum Posterior Density (MPD) estimates are presented. Given the large number of simultaneous uncertainties in this system, it would be senseless to try to estimate some parameters from the available data (e.g. growth, M, movement, probably steepness). In this case, the uncertainty associated with model selection is typically greater than the statistical uncertainty associated with any individual model. Thus emphasizing the range of MPD results is likely to provide a more realistic expression of uncertainty.

The WPB agreed to provide assessment results in a format that is consistent with the Kobe 2 Strategy Matrix in 2010. This is a decision table that expresses probabilistic statements about future outcomes of the fishery. In the case of swordfish, the WPB chose 3 and 10 year projections, using constant catches at levels of 80, 90, 100, 110, and 120% of 2008 levels.

For SS3, deterministic projections were conducted for some models (and only reported for model IO-7). There remains a problem of how to make the probabilistic statements expected in the Kobe 2 Strategy Matrix using this approach. Selecting a unique model with which to conduct stochastic projections will certainly understate the uncertainty. In addition, the current model configuration is not appropriate for generating stochastic projections.

Results and Discussion

The aggregate Indian Ocean assessment and SW sub-region assessment are presented separately below. Given the complexity of the models, it was not practical to show all of the detailed results for all of them. The approach used here is to provide detailed results 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 in case additional detail is required.

Aggregate Indian Ocean Assessment

Detailed results are shown for Model IO-7. This does not reflect preferential status of this model, but many of the diagnostic features are representative of the other SS3 specifications, and the life history assumptions are most comparable with the ASIA and SCAM models that were also presented to the 2010 WPB:

- Figure 9 and Figure 10 show the fit to the 10 CPUE series, and illustrate the following points which are typical of the aggregate IO models:
    - The fit to the northern area JPN and TWN CPUE is mostly reasonable (though there seem to be discontinuities that suggest possible shifts in catchability (e.g. , JPN in the NE 2000-1, TWN in the NW around 2003-4).
    - The fit to the SEZ CPUE trend is also reasonable given the level of noise in the series (noting that the SEZ CPUE was not informative in the model).
    - The fit to the southern area CPUE is generally poor. In the SE, there is no obvious evidence of a systematic failure to fit the data, but it is difficult to conclude that there is any trend in the CPUE series given the high level of noise in both the JPN and TWN series.
    - The SW region is the most poorly fit by all series, in that there appears to be a very steep decline in CPUE in the 1990s that was generally underestimated by the model.
- Figure 11 shows the time series of predicted and observed mean catch-at-size by fleet. In general, the fits are reasonable, and the better sampled fleets tend not to show any long term trends or systematic lack of fit. The JPN SW fleet represents a possible exception, in that the observed size composition increases over the 1990s, and drops in the early 2000s. The model does not predict substantive size trends for this or any other fleet.
- Figure 12 illustrates typical size-based selectivity estimates for the longline and gillnet/ associated fisheries. The dome-shaped pattern is plausibly consistent with the size/sex-based partitioning of the species, in which the largest, predominantly female individuals tend to be

caught in the extremes of the range. However, the dome-shape can also arise as an artefact of errors in the specification of natural mortality (including variability in M by age).

- Figure 13 illustrates the recruitment dynamics. There is some autocorrelation in the time series of deviations, but there is no obvious evidence of a serious systematic lack of fit.
- Figure 14 illustrates the biomass trends in each of the 4 sub-regions. The population appears to be fairly evenly distributed across the 4 regions. There is not much difference in the estimated depletion for the NW, NE and SW regions, while the SE region appears be the least depleted (consistent with historical perceptions).
-
- Table 5 describes the results of the 3 and 10 year constant catch projections, indicating that large changes in stock status over the next 10 years are not expected if catches remain within +/- 20% of 2008 levels.

For all of the aggregate IO models, convergence seemed to be reasonable, except for IO-13 and IO-14. These models suffered from numerical problems that remain unresolved. It is also possible that global minima might not have been consistently identified, as this was not tested. Summary diagnostic indices are presented for these models: Root Mean Square Error (RMSE) describes the fit to the CPUE series, and the Effective Sample Size (ESS) is a measure of the fit to the size composition data.

The RMSE for the fits to the 10 CPUE series are compared for all aggregate IO models (Figure 15). If the model was internally consistent, the RMSE should approximately equal the input SD for each CPUE series. The systematic lack of fit (e.g. auto-correlation of the CPUE errors) is usually more interesting than the RMSE per se. However, in these models, large RMSE generally indicates systematic lack of fit, such that the two measures are usually interchangeable for purposes of qualitatively comparing models based on the same data. From these plots we note:

- In all cases, it is evident that the fit to the Japanese and Taiwanese CPUE in the SW region is very poor. This is not too surprising since these series were usually highly down-weighted.
- Relaxing the CV of the recruitment deviations made very little difference to the fit to the SW CPUE series (IO-8), nor did (only) removing the shared catchability constraint for the JPN SW fleet (models IO-11,IO-12, not shown).
- The REU CPUE series always appears to be well fit from this index relative to the other series (because the time series is very short, and the systematic lack of fit is mostly determined by whether the single high point in 1994 is well fit). However, if the fit to the 1994 CPUE point really is an important indication of depletion, then the difference in REU RMSE among models is quite large, and the difference in fit is evident in comparing IO-7 (Figure 10) and IO-9 (with up-weighted REU CPUE Figure 16) . High weighting of the REU CPUE had the expected effect on improving the fit to the REU series, and made the stock status estimates a little more pessimistic. However, up-weighting REU had a minor effect on the fit to the other data, such that the effect of the other life history parameters was much more important on the stock status results (e.g. IO-2 and IO-9 are very similar, as are IO-5 and IO-10, while IO-2 and IO-5 are much more dissimilar).
- Applying a very high weight to the JPN or TWN SW CPUE series appeared to result in a substantive improvement to the fit of these series in the SW region (at the expense of the fit to the JPN series in the NW and NE). However, these models suffered from numerical problems that remain unresolved (e.g. IO-13, IO-14).

Two measures are used to describe the size composition fit (Figure 15). ESS indicates how well the predicted size composition data fits the observations (irrespective of the weighting for that data). An ESS of 200 for a given fleet means that on average, the fit is as good as would be expected for a true random sample of 200 (regardless of what the actual sample size was). As with the RMSE, the ESS does not really describe the systematic lack of fit to the size composition data, but as a relative index among models, a decline in ESS is usually associated with a systematic lack of fit (if sample sizes are substantial). The ratio, ESS/N, describes how well the model fits the data, relative to the assumption about how well the model should fit the data given the assumed sample sizes (i.e. in an ideal world, a true random sample of 1000 should have an assumed sample size of 1000, an ESS of around 1000, and a ratio near 1.0). If the model fits better (worse) than the input assumption, the ratio will be greater than (less than) than 1. From these plots we note that:

- The European (Spanish) fleets in the SW and SE region have the best fit to the size composition data. To some extent this is reassuring because the Spanish fleet is perceived to have more consistent targeting practices than the JPN and TWN fleets, and substantial observer sampling programmes.

- The JPN fleet clearly has the highest ratio of ESS/N (in the NE and SE regions), which is mostly a reflection of the small sample sizes for this fleet, rather than particularly good agreement between the model and size composition data.
- Some of the fleets have a relatively poor fit to the size composition data relative to the assumed sample sizes (e.g. including the European fleet in the SE, which is the second best fit fleet in terms of the ESS).
- Given the small samples from many of these fleets in recent years, it is difficult to conclude much from these observations. The more important observation is that these quality of fit indices were reasonably stable among all of the models examined (i.e. including the model with all size composition indices down-weighted by a factor of 10).

While the size composition data merits closer scrutiny in the future (i.e. to consider the issues of changing selectivity, non-random sampling, uncertain growth rates, etc.), at this time it does not appear to be particularly informative for comparing models in the aggregate IO region (but this conclusion differs for the SW sub-region model described below).

Table 4 provides comparative summary statistics for all of the aggregate Indian Ocean models. Figure 17 illustrates the stock status time series B/BMSY, F/FMSY and B/B0, and Figure 18 compares the 2008 stock status estimates in a Kobe plot. These results show a large degree of sensitivity to the model assumptions. The models were sensitive to life history assumptions in predictable ways (i.e. higher steepness, higher M, faster growth and younger maturity are consistent with a more productive stock with a higher MSY). Given the conflicting trends among various data sources, and high uncertainty in many other biological assumptions, it is very difficult to justify a unique model selection at this time. However, the point estimates are consistent in suggesting that the current stock status is reasonable from a conservation perspective (SSB $\geq$ 1.73 BMSY, SSB $\geq$ 0.39 SSB0 and F $\leq$ 0.78 FMSY). However, it should be noted that this conclusion reflects the somewhat subjective selection of assumptions that happened to be tested, and they do not admit the statistical uncertainty associated with any individual model. It is expected that more pessimistic scenarios could be fit, and justified as being equally plausible to the models presented here. Furthermore, the current model structure lacks the flexibility to fit some of the pessimistic data in the SW region. If the more pessimistic data in the SW region are valid, this will probably have a negative impact on the aggregate Indian Ocean assessment. The more serious implications for the SW region are discussed below.

SW Sub-Region Model

Detailed results are shown for Model IO-7sw. As with the aggregate IO models, this selection does not indicate preferential status, but it does show some central results, and maintains consistency with the ASIA and SCAM life history assumptions (that were also presented to the 2010 WPB):

- Figure 19 shows the model fit to the 3 SW CPUE series. The SW sub-region model clearly can describe the decline in SW JPN CPUE in the 1990s better than the aggregate model. The fit to the REU series is also better than the aggregate IO models (those without preferential weight on the SW CPUE series).
- When JPN, TWN and REU CPUE series are weighted equally, the model favours a very steep population decline over the most recent 5 years that most closely corresponds to the TWN series during that time period. However, there are good reasons to be sceptical of the models that follow the pessimistic recent Taiwanese trend, as discussed below.
- Figure 20 shows the time series of predicted and observed mean catch size by fleet. In general the fits are reasonable and similar to the aggregate IO models. However, the JPN SW fleet again represents the exception, in that the observations suggest trends in mean size that are not well described by the model, and conflict with the other fleets in the region. This again raises some question about the consistency of operations (or sampling) of the JPN fleet.
- Figure 21 shows the similar dome-shaped selectivity for the SW sub-region as was observed for the aggregate Indian Ocean longline fishery.
- Figure 22 shows the estimated recruitment dynamics. There is a systematic lack of fit between the assumed steepness and the estimated recruitment time series. However, the model is consistent with the other SW sub-region models in that the early trends in the JPN CPUE series could only be fit with anomalous recruitment (i.e. above average in the 1980s

and below average in the 1990s) in addition to the fishery impact. The models which estimate steepness (IO-7swj2, IO-7swns2) prefer a lower steepness (0.61, 0.68), which reduces some of the systematic lack of fit (not shown), but does not remove the need for anomalous recruitment.

The RMSE for the fits to the 3 CPUE series are compared for all SW models (Figure 23), which clearly illustrates the conflict between JPN and TWN CPUE series. Highly weighting one causes a failure in fit of the other. As would be expected, equal weighting results in a mediocre fit to both series. The REU series seems to fit reasonably well regardless, because it is consistent with both series during the period in which they overlap. The fit to the 3 CPUE series are compared for IO-7swj (JPN series highly weighted) and IO-7swt (TWN series highly weighted) in Figure 24.

The alternative SW sub-region model specifications provide very different fits to the size composition data (ESS indices shown in Figure 23), for the European fleets. Changes in the fit to the JPN and TWN size data as indexed by the ESS are much less noticeable, presumably because the fit was not very good to begin with for these series. Up-weighting the Japanese and Taiwanese CPUE series (or down-weighting the size data, which is roughly equivalent to up-weighting all of the CPUE series) causes a considerable decrease in the fit to the European size composition data. The predicted trend in declining mean size over recent years as favoured by the CPUE series (e.g. model IO-7swnsm, Figure 25) is not evident in the data.

Table 4, Figure 26, and Figure 27 illustrates the large range in stock status estimates derived from the SW sub-region models presented here. The models all show large biomass declines during the 1990s, but most suggest that the biomass was well above average unfished levels due to high recruitment in the 1980s-90s. The scenarios range from very pessimistic (B/B0< 0.01 for IO-7swns) to much more moderate and comparable to the aggregate IO stock status (B/B0 = 0.43 for IO-7sws100). The range would presumably be even greater if the alternative life history assumptions were included. The main data conflicts are summarized:

- The JPN and TWN CPUE series in the last 5 years clearly have substantial and opposing trends.
- The Japanese size composition data suggests mean size trends that are not evident in the other size composition data.
- The size composition data for the European fleets does not seem to support the very high levels of depletion or recruitment anomalies suggested in the JPN and TWN CPUE series.

In considering how to interpret these conflicts, it is worth re-iterating the main features of the data:

- JPN CPUE – swordfish is (mostly) a by-catch species, and the fleet has changed its tuna targeting in the region over time, between Yellowfin, Bigeye and Southern Bluefin Tunas. The standardization is sensitive to assumptions about the spatial definition of the fishery, such that the timing of the very large drop in CPUE in the early 1990s can change by several years (Figure 7) and seems to predate the large reported swordfish catches in the early 1990s. If targeting changes can explain the magnitude of the sharp decline in CPUE in the 1990s, this can presumably also explain the recent increase in CPUE over the last 5 years.
- JPN catch-at-size – if targeting has been changing catchability, there is reason to expect that that it could also affect selectivity. But sample sizes are very small and declining in this fleet in recent years.
- TWN CPUE series – It is known that some elements of the Taiwanese fleet in the SW switched from targeting albacore to swordfish in the 1990s. This was associated with very large increases and then decreases in nominal catch rates. The increases were undoubtedly related to targeting shifts toward swordfish, while the decreases were probably a combination of depletion and targeting shifts away from swordfish toward tropical tuna. The effort of the Taiwanese fleet in the Indian Ocean has declined markedly in the last few years, and the very low 2008 CPUE observation in particular may be an artefact of a trivial amount of effort.
- TWN size composition – In 2010, there was a large revision in the size composition data for the last few years. At this time, it is unclear whether this revision needs to be extended further back in time. It seems reasonable to expect that the large changes in targeting could affect selectivity as well as catchability.
- REU CPUE – the standardized CPUE series is based on the small region in the vicinity of Reunion. The fleet is thought to have operated reasonably consistently through the late 1990s,

and the REU, JPN and TWN fleets seem to have consistent trends during the period of overlap. The nominal CPUE series has been reasonably stable over the past few years (Kolody et al. 2010a). The fleet is known to have shifted toward BET targeting in the past decade, but it is unclear whether this shift affects the swordfish CPUE trend within the last 5 years (if so, the real swordfish trend would probably be more positive).

- REU size composition data - there is no evidence for changes in swordfish size composition since the mid-1990s in this fleet (though the sampling was better in the 1990s than in recent years)
- Spanish CPUE – this fleet is believed to have always targeted swordfish (and shark). The fleet underwent a major shift to 'American-style' gear around 2000-2001, which clearly indicates that catchability can rapidly increase (or decrease) by a factor of 5 or more. The nominal CPUE series in the last 5 years has been relatively stable, or possibly trending slightly downward (WPB 2010).
- Spanish size composition – there is a large amount of high quality observer-based size sampling in this fleet. As a dedicated targeting fleet, the selectivity might be expected to be more stable than the JPN and TWN fleets.

The SCAM stock status results described in Martell (2010) resemble the more central estimates produced by SS3. However, there are a couple notable differences:

- SCAM does not use the size composition data, and the SS3 results are shown to be sensitive to these data. Given the size composition problems (longlines select larger/older individuals, possibly changing selectivity over time, and poor smapling for some fleets), it is not surprising that interannual recruitment variability is not well resolved in this fishery. However, it would be difficult to ignore the absence of long-term size composition changes that are predicted by large sustained recruitment anomalies and very high depletion.
- When stock-recruitment steepness was estimated, the SCAM results were driven toward the upper bound of 1, while the SS3 results preferred lower levels 0.61 – 0.68. The reason for this discrepancy is unclear, particularly since SS3 preferred lower steepness even when the size composition data were down-weighted. Presumably it relates to the interactions among the other assumptions which were not consistent between SCAM and SS3.
- The SCAM results were sensitive to the dubious 2008 TWN CPUE point, which was removed from reported results. This was not explicitly examined with SS3.

Overall, the interpretation of the SW stock status remains unclear, and the data conflicts cannot be resolved within an assessment model. The very steep population declines in the early 1990s as estimated by the Japanese CPUE may are questionable and should be corroborated by additional data. Similarly, the most pessimistic models which predict very steep population declines over the last 5 years do not seem to be plausibly consistent with important sources of quality data (that were not included in the assessment models). Further emphasis on analysing the conflicting data inputs is required. Particular emphasis should be placed on:

- Updating the standardization of the Spanish and La Reunion CPUE series to include the most recent data.
- Further attempts to account for species targeting switches in the JPN and TWN fleets.
- Evaluating the different size composition series in relation to i) quality of sampling programmes, ii) targeting/selectivity shifts, iii) data processing issues (e.g. size conversions, spatial partitioning).

Conclusions:

- The SS3 model is a powerful, flexible framework for integrating a diverse range of structural features and statistical assumptions for the assessment of Indian Ocean swordfish. The current configuration includes a level of detail that may not be required purely for stock status inferences. However, given the poor level of understanding of this fishery, this approach has proved useful for examining the implications of many alternative assumptions, and illustrating the risk of aggregating disparate and potentially conflicting data. The computational burden of the approach is not overwhelming for the purposes of calculating MPD parameter estimates, but would be prohibitive for evaluating Bayesian posteriors. One noted shortfall with SS3 is the inability to resolve year-area interactions in recruitment variability, which would be useful for exploring some spatial processes within an aggregate Indian Ocean model.

- The models applied to the aggregate Indian Ocean swordfish population in 2010 again indicated a number of sensitivities that cannot be easily dismissed. However, all of the MPD estimates from the most plausible models consistently inferred that the current stock status did not represent an immediate conservation risk (i.e. for 2008, SSB ≥ 1.73 BMSY, SSB ≥ 0.39 SSB0 and F ≤ 0.78 FMSY). These results were somewhat more optimistic than last year, and presumably attributable to i) the continuing decline in longline catch and effort in the Indian Ocean, ii) new CPUE analyses, iii) revisions to the Taiwanese size composition data, and iv) different emphasis on life history assumptions. However, none of the aggregate IO models provided an adequate fit to the data in the SW region.

- The WPB had intended to focus special attention on the SW region in 2010. It was hoped that this could essentially be completed using the spatially disaggregated SS3 model, but the model did not have sufficient flexibility to fit the contrasting CPUE trends among areas. However, a separate model-based assessment (SCAM) of the SW region (conducted under the assumption that it may represent an isolated stock) was successful in describing the perception of elevated depletion in that region, with potentially serious stock status implications (Martell 2010). Subsequent to the WPB, the SS3 model was similarly adapted to represent the SW population (unlike SCAM, the SS3 model included the size composition data and estimated the selectivity function). The following points are noted regarding the SW assessments:
    - i. There is a strong conflict between the SW JPN and TWN CPUE series in the last few years, such that it is not possible to fit a strong increase and decline at the same time. Some years of TWN effort included in the core area standardization analysis may suffer from small sample sizes, but this could not be confirmed (and may explain the rapid CPUE drop in the last year in particular). Nominal CPUE series from Spain and Reunion were relatively stable during this same period (and not included in the models).
    - ii. The steepest JPN CPUE decline occurs immediately before the large catches of the early 1990s. These models (SCAM and SS3) cannot explain the decline through fishing mortality alone, and anomalous recruitment must also be invoked (i.e. a substantial peak followed by a substantial trough).
    - iii. The SS3 results indicate that there is a very large degree of uncertainty in the SW stock status, with some model results alarmingly pessimistic and others suggesting that the stock status is possibly no worse than the aggregate Indian Ocean stock. Martell 2010 describes 2 specifications of SCAM for the SW, and the stock status inferences are generally consistent with the intermediate results observed for SS3.
    - iv. It is difficult to objectively decide how to interpret the conflicting data sources, and alternative biological assumptions (noting that the uncertainty would be inflated further if alternative growth and M assumptions were explored for the SW). However, the models with very steep declines estimated over the last 5 years do not seem to be plausibly consistent with some key sources of data (CPUE from Spanish, REU and JPN fleets; size composition from Spanish and REU fleets).

- At this time it is difficult to have much confidence in the results of any particular model for either the aggregate Indian Ocean or the SW because:
    - i. Results tend to be sensitive to life history parameters that are poorly quantified (i.e. there is no direct age validation underpinning growth rate estimates, no tagging estimates of M, stock-recruit steepness is always difficult to estimate).
    - ii. CPUE is strongly influenced by poorly-quantified targeting shifts, the trends are sensitive to standardization techniques, and the series from different fleets conflict in most areas (and seem to be extraordinarily noisy in other areas).
    - iii. Size composition sampling is often poor, longline selectivity tends to provide little information on relative cohort strength, and it is likely that targeting shifts affect selectivity, such that the separable assumption is also questionable.

- There are a number of longer term paths of investigation that might help reduce the assessment uncertainties, including:
    - i. Review stock structure in relation to new genetics and tagging work. A more effective (and more precautionary) method for dealing with the unknown stock structure would be

to assume several independent stocks unless compelling evidence to the contrary can be provided. The SW remains the highest priority for this approach.

ii. Continued analysis of catch rates to identify and quantify consistent fishing practices. The CPUE analyses should include more explicit consideration of other species, and additional analyses to better understand the mechanisms of interaction between catchability and environmental factors. The Spanish and Reunion CPUE series should be revisited in the SW region for recent years and adopted in the assessment models as a priority).
iii. Review the swordfish size composition data for the purposes of identifying homogenous fleet characteristics that are more likely to conform to constant selectivity (and shared catchability) assumptions.
iv. Age validation work should be conducted (e.g. growth increments observed in tags, and oxy-tetracycline marks to validate fin spine annulus counts).
v. Additional work on quantifying catch uncertainty is encouraged.

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

ALGI	Contains data for gillnet, trolling and other minor artisanal fisheries
AUEL	Contains data for the longline fishery of Australia (target is SWO)
EUEL	Contains data for EU longliners (from Spain, Portugal and the UK) targetting SWO plus other longliners assimilated to EU longliners (generally owned by Spanish nationals)
ISEL	Contains data for the semi-industrial longline fleets operating in Reunion(France), Mayotte(France), Madagascar, Mauritius and the Seychelles, which also target SWO
JPLL	Contains data for the longline fishery of Japan plus other fleets assimilated to the Japanese fleet (e.g. South Korea, Thailand, Oman)
TWFL	Contains data for the fresh-tuna longline fleets of Taiwan and Indonesia, plus other fresh-tuna longline fleets assimilated to those and all sport fisheries and fleets operating hand lines
TWLL	Contains data for the large scale tuna longline fleet of Taiwan,China, plus other longline fleets assimilated to the Taiwanese fleet (a component of those fleets may target SWO)
ALGI	Contains data for gillnet, trolling and other minor artisanal fisheries

Fleet Number	Name	CPUE Series Number
1	ALGI_NW	
2	EUEL_NW	
3	ISEL_NW	10 (Seychelles)
4	JPLL_NW	1
5	TWFL_NW	
6	TWLL_NW	5
7	ALGI_NE	
8	EUEL_NE	
9	JPLL_NE	2
10	TWFL_NE	
11	TWLL_NE	6
12	ALGI_SW	
13	EUEL_SW	9 (Reunion)
14	ISEL_SW	
15	JPLL_SW	3
16	TWFL_SW	
17	TWLL_SW	7
18	ALGI_SE	
19	AUEL_SE	
20	EUEL_SE	
21	ISEL_SE	
22	JPLL_SE	4
23	TWFL_SE	
24	TWLL_SE	8

Table 2. SS3 specifications for the aggregate Indian Ocean assessment.

Model ID	Japanese CPUE SD(log) (LLH-weighting)	Taiwanese (case 4) CPUE SD(log) (LLH-weighting)	La Reunion Seychelles CPUE SD(log) (lambda)	Gillnet catch-at-size LLH-weighting	Longline catch-at-size LLH-weighting	Growth and Mortality	Beverton-Holt Steepness SD(log(devs))
IO-2	Q shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (1) 0.1 (0.00001)	1	1	Growth Slow M=0.2	0.9 (0.2)
IO-3	Q shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (1) 0.1 (0.00001)	1	1	Growth Slow M=0.2	0.7 (0.2)
IO-4	Q shared 0.1 (NW 1) (NE 1) (SW 0.0001) (SE 0.1)	Q not shared 0.1 (NW 0.00001) (NE 0.00001) (SW 0.00001) (SE 0.00001)	0.1 (1) 0.1 (0.00001)	1	1	Growth Slow M=0.2	0.9 (0.2)
IO-5	Q shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (1) 0.1 (0.00001)	1	1	Fast Growth M=0.4	0.9 (0.2)
IO-6	Q shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (1) 0.1 (0.00001)	0.1	0.1	Growth Slow M=0.2	0.9 (0.2)
IO-7	Q shared 0.1 (NW 1)	Q not shared 0.1 (NW 1)	0.1 (1) 0.1 (0.00001)	1	1	Growth TWN M=0.25	0.9 (0.2)

	(NE 1) (SW 0.00001) (SE 0.1)	(NE 1) (SW 0.00001) (SE 0.1)					
The following models were fit after the WPB 2010							
IO-8 Relax Rec CV	Q shared 0.1 (NW 0.1) (NE 0.1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (1) 0.1 (0.00001)	1	1	Growth Slow M=0.2	0.9 (0.6)
IO-9 Force SW CPUE fit, relax Q by area constraint	Q shared for A1,2,4 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (100) 0.1 (0.00001)	1	1	Growth Slow M=0.2	0.9 (0.2)
IO-10 Force SW CPUE fit, relax Q by area constraint Fast life history	Q shared for A1,2,4 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (100) 0.1 (0.00001)	1	1	Fast Growth M=0.4	0.9 (0.2)
IO-11 Do not force Force SW CPUE fit, relax Q by area constraint	Q shared for A1,2,4 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (1) 0.1 (0.00001)	1	1	Growth Slow M=0.2	0.9 (0.2)
IO-12 Do not force Force SW CPUE fit, relax Q by area constraint	Q shared for A1,2,4 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (1) 0.1 (0.00001)	1	1	Fast Growth M=0.4	0.9 (0.2)

Fast life history							
IO-13 Force SW CPUE fit, relax Q by area constraint	Q shared for A1,2,4 0.1 (NW 1) (NE 1) (SW 10.0) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (10) 0.1 (0.00001)	1	1	Growth Slow M=0.2	0.9 (0.2)
IO-14 Force SW CPUE fit, relax Q by area constraint Fast life history	Q shared for A1,2,4 0.1 (NW 1) (NE 1) (SW 10.0) (SE 0.1)	Q not shared 0.1 (NW 1) (NE 1) (SW 0.00001) (SE 0.1)	0.1 (10) 0.1 (0.00001)	1	1	Fast Growth M=0.4	0.9 (0.2)

Table 3. SS3 specifications for the SW sub-region assessment.

Model ID	Japanese CPUE SD(log) (LLH-weighting)	Taiwanese (case 4) CPUE SD(log) (LLH-weighting)	La Reunion Seychelles CPUE SD(log) (lambda)	Longline catch-at-size LLH-weighting	Growth and Mortality	Beverton-Holt Steepness SD(log(devs))
IO-7sw SW only	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)	0.1 (1.) 0.1 (0.00001)	1	Growth TWN M=0.25	0.9 (0.6)
IO-7swJ SW only	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 10.) (SE 0.0000001)	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 0.1) (SE 0.0000001)	0.1 (0.1) 0.1 (0.00001)	1	Growth TWN M=0.25	0.9 (0.6)
IO-7swJ2 SW only	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 10.) (SE 0.0000001)	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 0.1) (SE 0.0000001)	0.1 (0.1) 0.1 (0.00001)	1	Growth TWN M=0.25	Est. = 0.68 (0.6)
IO-7swR SW only REU wt	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 0.1) (SE 0.0000001)	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 0.1) (SE 0.0000001)	0.1 (10.) 0.1 (0.00001)	1	Growth TWN M=0.25	0.9 (0.6)
IO-7swT SW only TWN wt	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 0.1) (SE 0.0000001)	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 10.) (SE 0.0000001)	0.1 (0.1) 0.1 (0.00001)	1	Growth TWN M=0.25	0.9 (0.6)
IO-7swns SW only	Q shared 0.1	Q shared 0.1	0.1 (1.) 0.1 (0.00001)	1E-7	Growth TWN M=0.25	0.9 (0.6)

Size down-weighted	(NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)	(NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)				
IO-7swNS2 SW only Size down-weighted h estimated	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)	0.1 (1.) 0.1 (0.00001)	1E-7	Growth TWN M=0.25	est = 0.68 (0.6)
IO-7swS100 SW only Size up-weighted by 100	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)	Q shared 0.1 (NW 0.0000001) (NE 0.0000001) (SW 1.) (SE 0.0000001)	0.1 (1.) 0.1 (0.00001)	100.	Growth TWN M=0.25	est = 0.61 (0.6)

Table 4. MPD Stock Status results for the aggregate Indian Ocean models.

Model	F/FMSY	B/BMSY	B/B0	MSY
Models fit during WPB 2010				
io2) Base specification	0.45	3.14	0.47	26
io3) steepness = 0.7	0.78	1.86	0.47	19
io4) TWN CPUE down-weighted	0.51	3.03	0.46	25
io5) Fast life history	0.33	2.15	0.52	46
io6) Size data down-weighted	0.49	2.68	0.40	26
IO-7) TWN life history	0.32	3.29	0.55	32
Models fit after WPB 2010				
io8) Recruitment sigma relaxed	0.48	2.90	0.44	26
io9) SW Q free REU CPUE up-weighted	0.63	2.54	0.39	22
io10) SW Q free REU CPUE up-weighted Fast life history	0.42	1.73	0.48	42
io13) SW Q free JPN CPUE up-weighted	Numerical failure			
io14) SW Q free JPN CPUE up-weighted Fast life history	Numerical failure			

Table 5. Biomass results for model IO-7 constant catch projections (relative to catch in 2008).

Catch Projection	**B2011/BMSY**	**B2018/BMSY**	**B2011/B2008**	**B2018/B2008**	**B2011/B0**	**B2018/B0**
0.8 C(2008)	3.12	3.25	0.95	0.99	0.52	0.54
0.9 C(2008)	3.10	3.07	0.94	0.93	0.52	0.51
1.0 C(2008)	3.08	2.89	0.94	0.88	0.51	0.48
1.1 C(2008)	3.06	2.71	0.93	0.83	0.51	0.45
1.2 C(2008)	3.03	2.53	0.92	0.77	0.51	0.42

Table 6. MPD Stock Status results for SW sub-region models.

Model	F/FMSY	B/BMSY	B/B0	MSY
All Models fit after WPB 2010				
IO-7sw	1.97	0.83	0.132	8.8
IO-7swj JPN CPUE up-weighted	0.23	2.09	0.333	15.7
IO-7swJ2 JPN CPUE up-weighted Steepness estimated	0.47	1.16	0.332	10.6
IO-7swR REU CPUE up-weighted	3.32	0.31	0.049	5.8
IO-7swT TWN CPUE up-weighted	1.33	1.55	0.251	9.1
IO-7swns Size data down-weighted	6.43	0.03	0.004	6.5
IO-7swNS2 Size data down-weighted Steepness estimated	10.14	0.04	0.012	5.1
IO-7swS100 Size data up-weighted	0.84	2.69	0.432	5.3

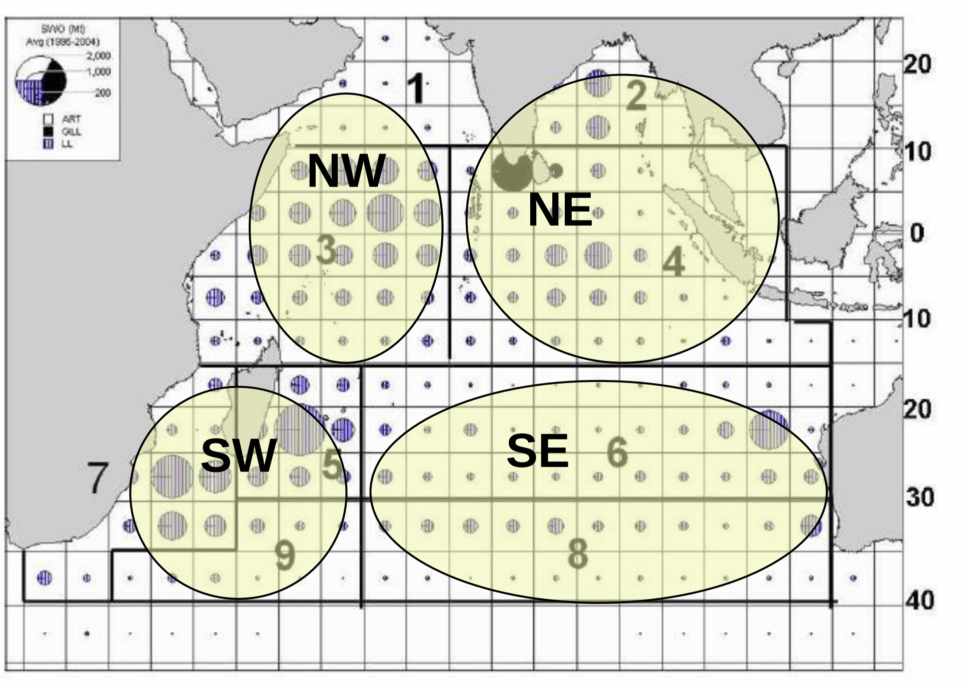

Figure 1. Spatial structure showing the 4 areas used in the model, superimposed on the IOTC statistical areas, and the swordfish catch distribution aggregated over 1995-2004.

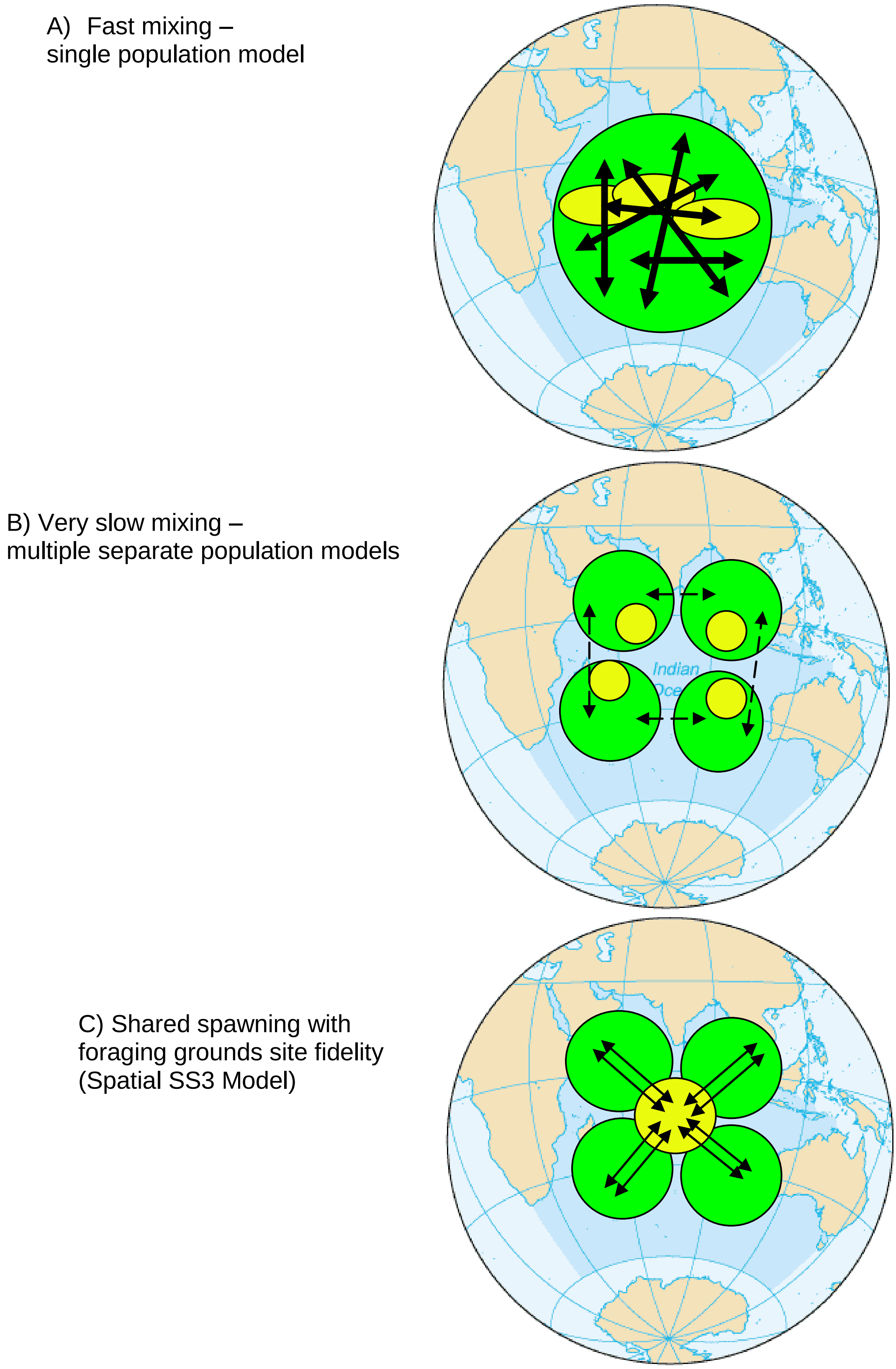

Figure 2. Cartoon of some alternative Indian Ocean swordfish population spatial hypotheses. Green circles represent foraging grounds, yellow circles represent spawning grounds, and arrows indicate movements.

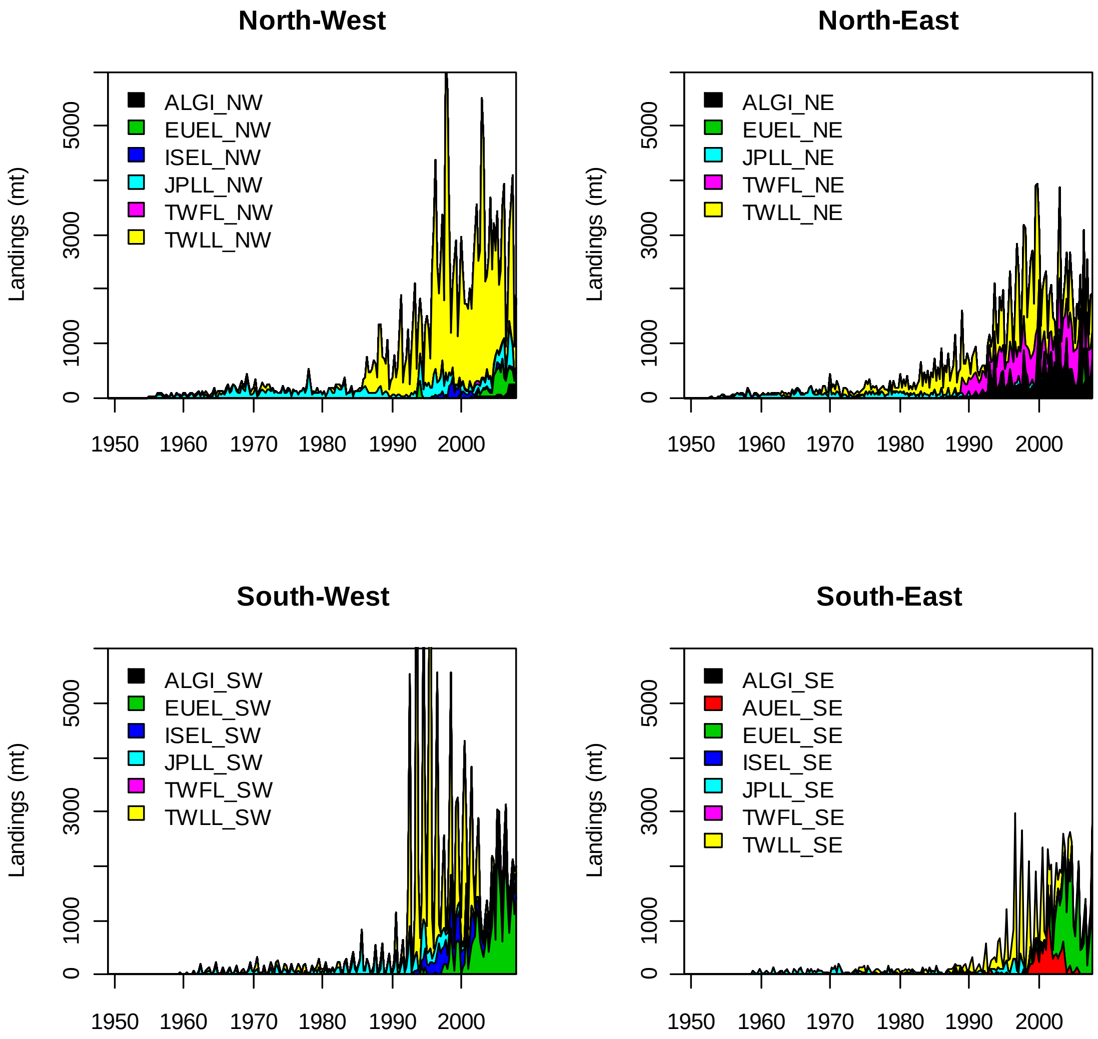

Figure 3. Total catch in mass over time (quarters) by assessment area and fleet. Note that 3 observations with quarterly catches approaching 10000 t are off the scale in the southwest. This is the figure from 2009, which omits the 2008 data, and will have minor errors in the Taiwanese catches due to a revision of the recent size data.

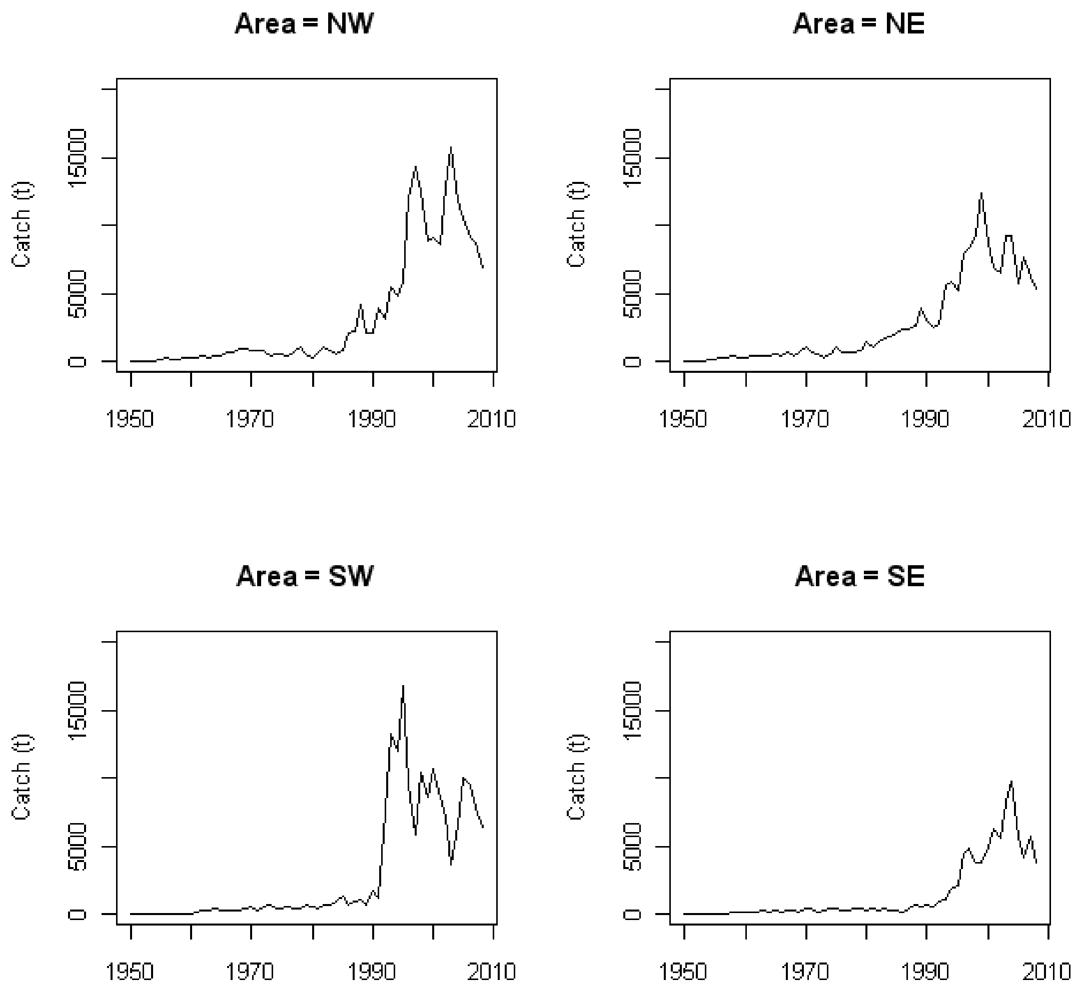

Figure 4. Total swordfish catch in mass by year and area.

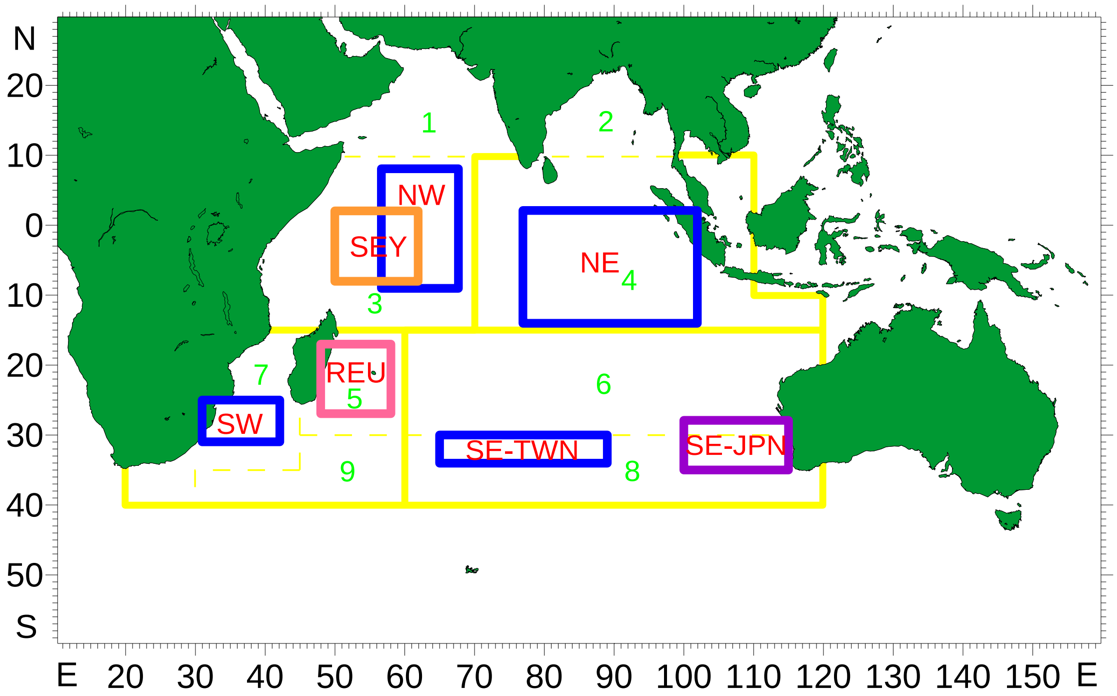

Figure 5. Map illustrating the core areas from which the 10 different standardized CPUE series were calculated (courtesy of Sheng-Ping Wang, Taiwan). Each CPUE series was considered to be an abundance index for one of the 4 broader regions used in the assessment (roughly corresponding to the large yellow boxes). JPN and TWN used the same core area for the NW, NE and SW, but different areas for the SE.

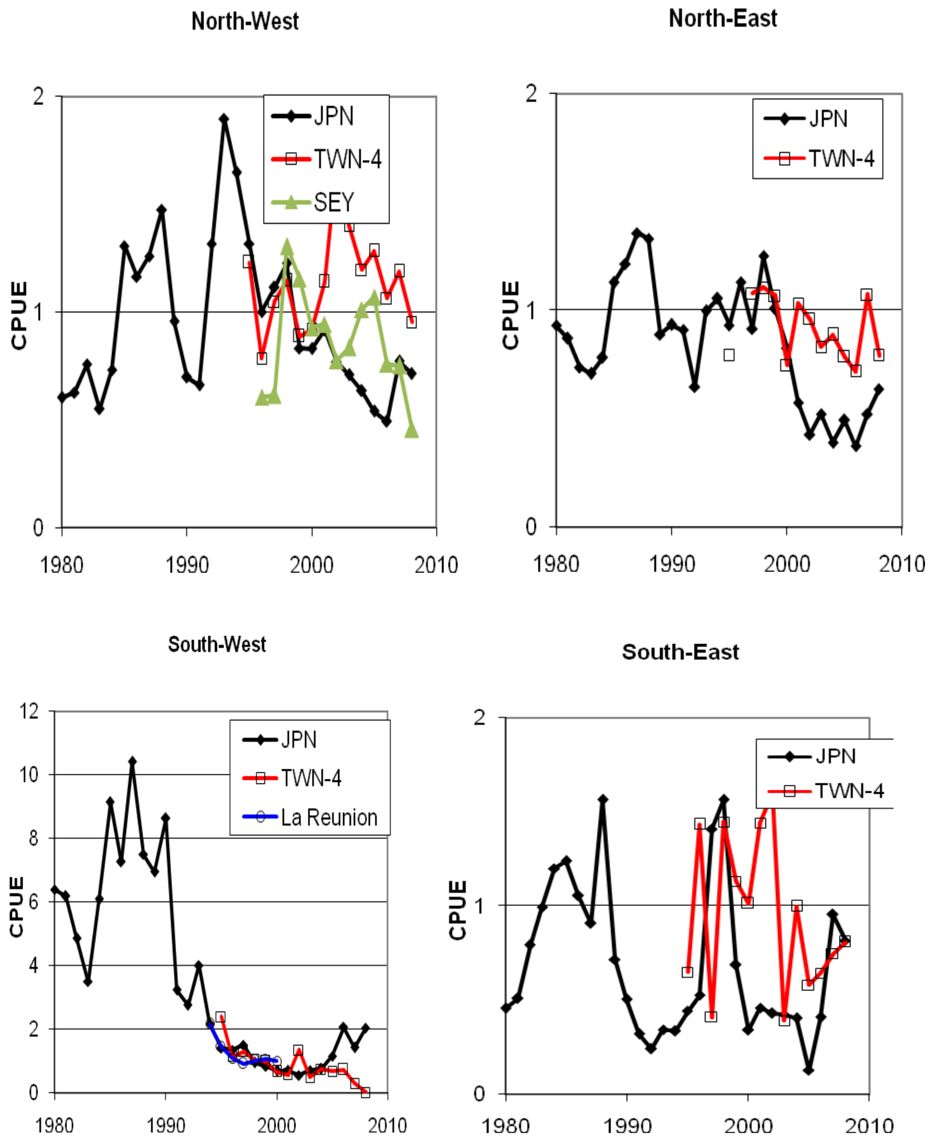

Figure 6. Standardized CPUE by area for Japanese, Taiwanese, La Reunion and Seychelles semi-industrial longline fleets. All series have been rescaled to have a mean of 1 over the interval 1997-2000 (note that this re-scaling is undertaken for the purposes of comparing trends among fleets within each area, and does not reflect the relative weighting across areas that is used in the assessment).

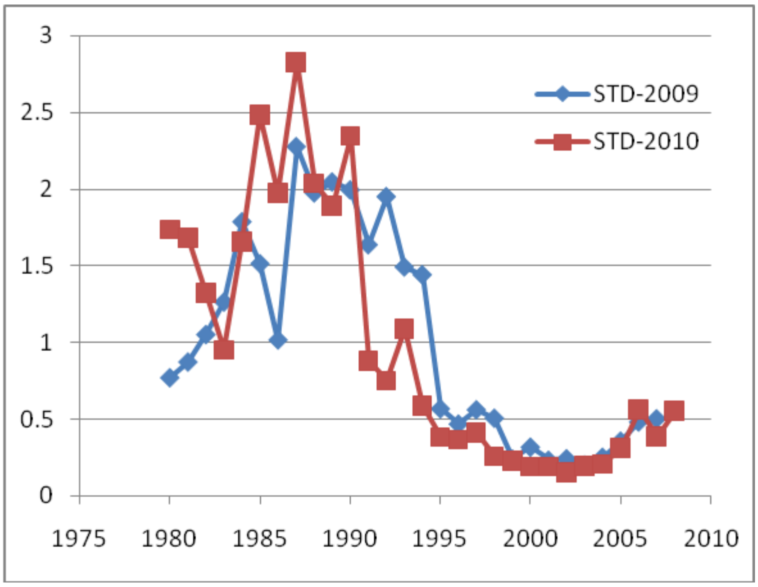

Figure 7. Comparison of standardized JPN CPUE in the SW region based on the analyses conducted in 2009 and 2010 (rescaled relative to the 1980-2007 mean).

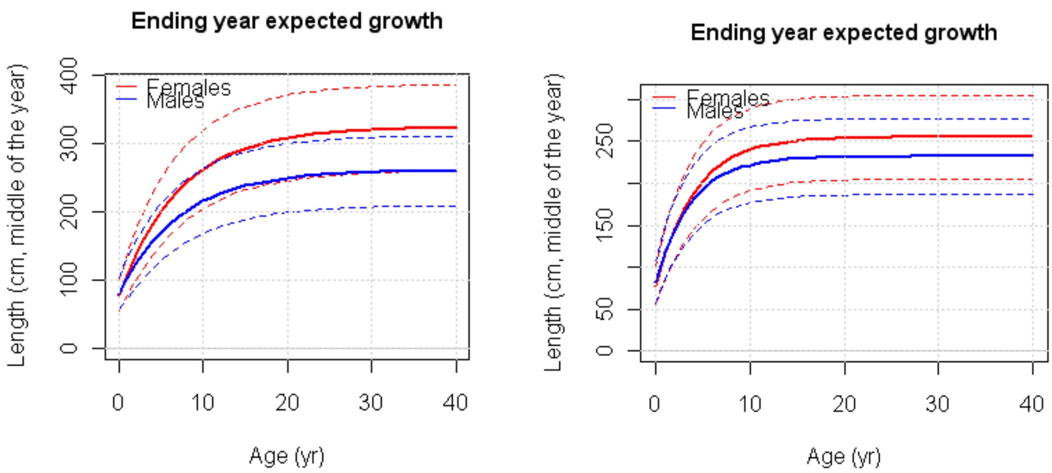

Figure 8. Slow (left panel, Young and Drake 2004) and fast (right panel, DeMartini et al.2007) growth rates assumed in different swordfish assessment models.

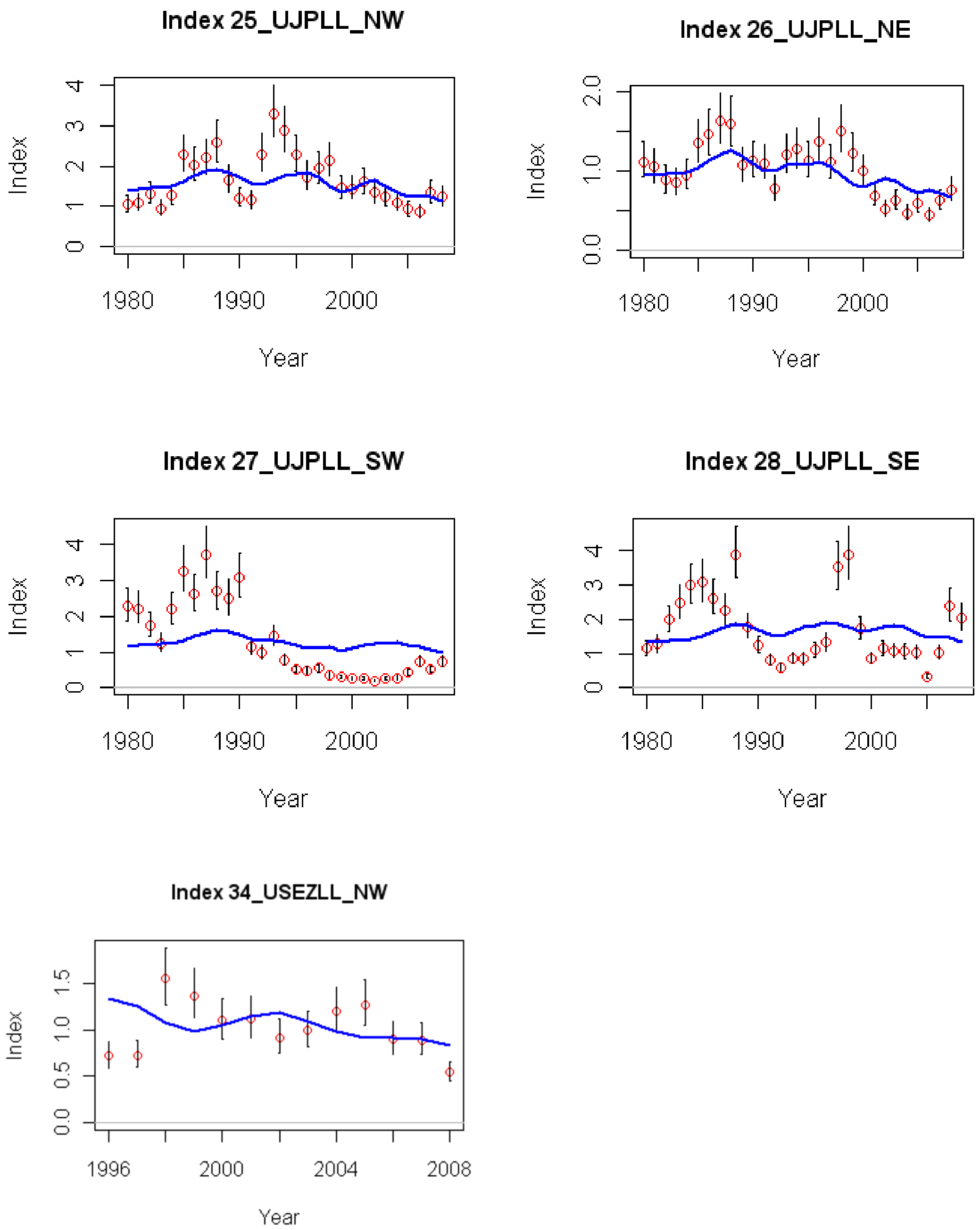

Figure 9. Predicted (line) and observed (circles) CPUE for the JPN and SEZ longline fisheries for the aggregate Indian Ocean model IO-7. Bars indicate the 95% Confidence Intervals for an assumed CV of 10% (error bars are meaningless for the SEZ CPUE because the CV was greatly inflated).

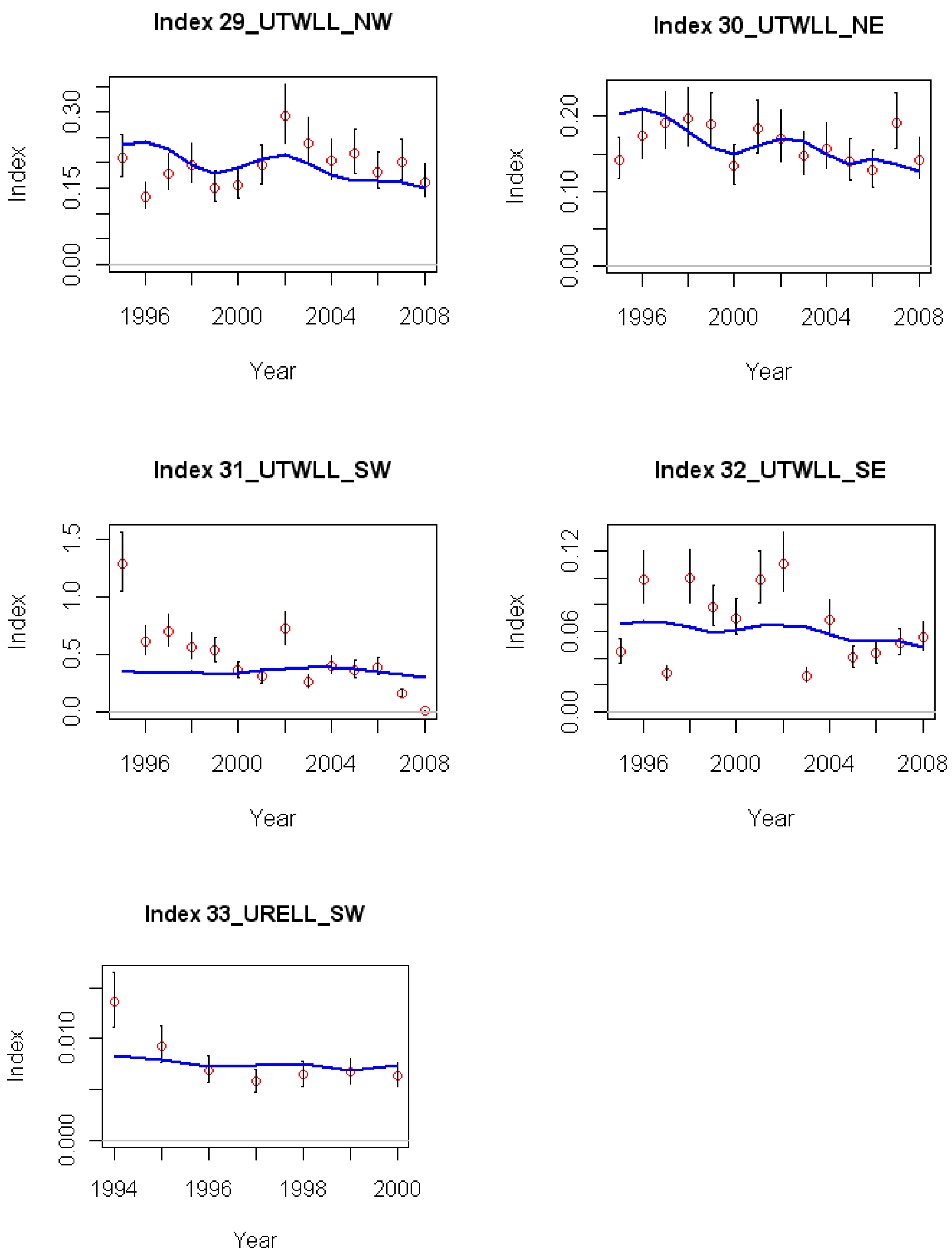

Figure 10. Predicted (line) and observed (circles) CPUE for the TWN and REU longline fisheries for the aggregate Indian Ocean model IO-7. Bars indicate the 95% Confidence Intervals for an assumed CV of 10%.

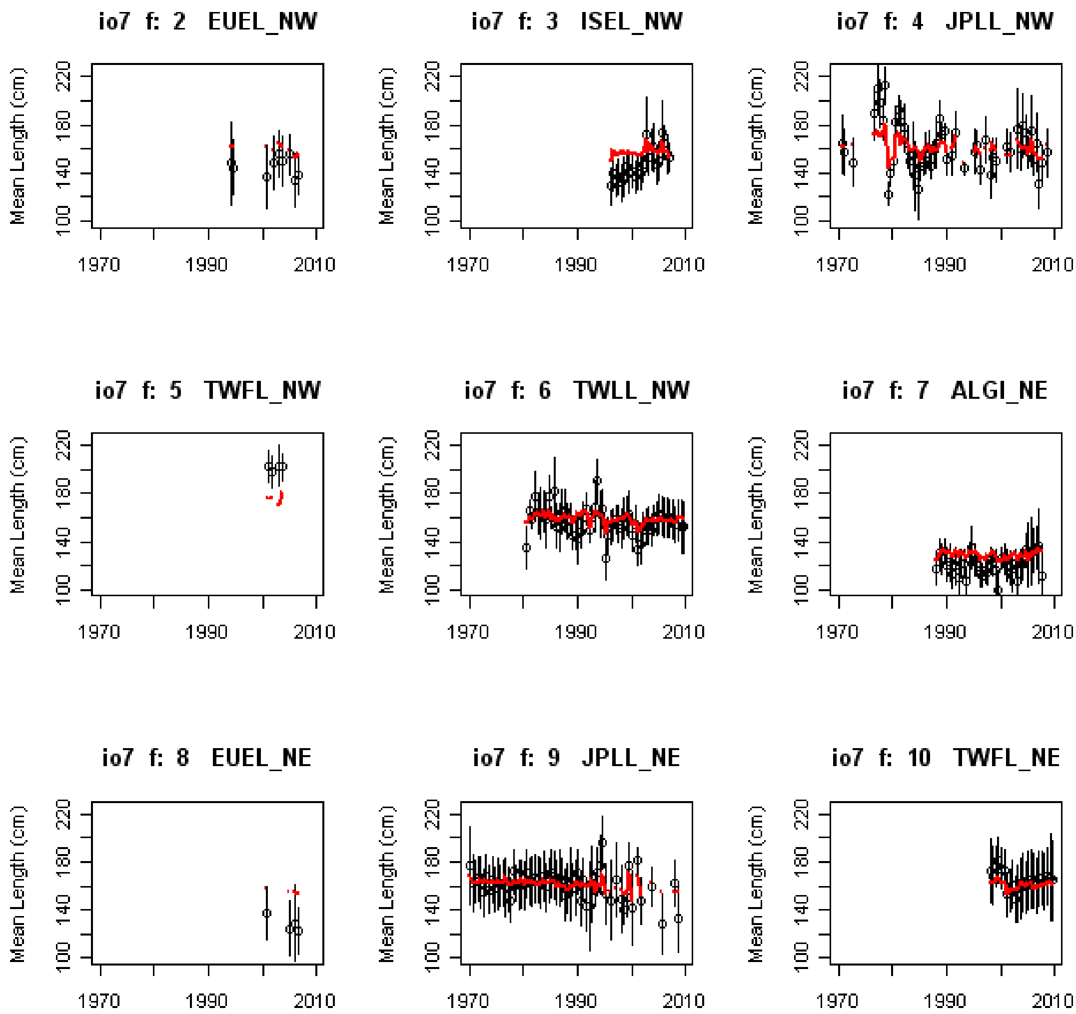

Figure 11. Predicted (red lines) and observed (black circles) mean catch-at-size for each of the 18 fleets with size composition data, for the aggregate Indian Ocean model IO-7. Note that the SS3 predicted mean catches are not quite right because only predicted size bins with corresponding observation bins are included in the calculation (i.e. there will be a bias when sample sizes are small). (continued over)

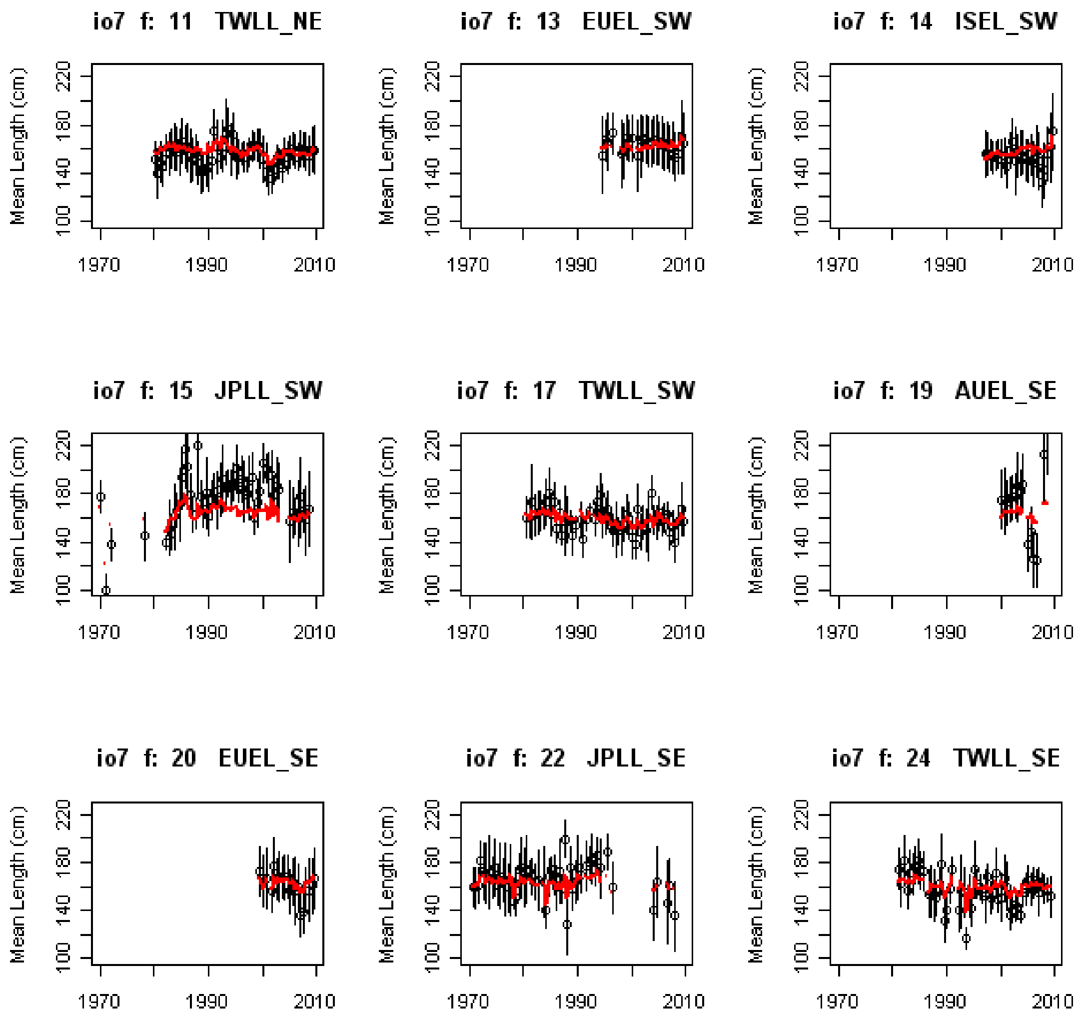

Figure 11 (cont.)

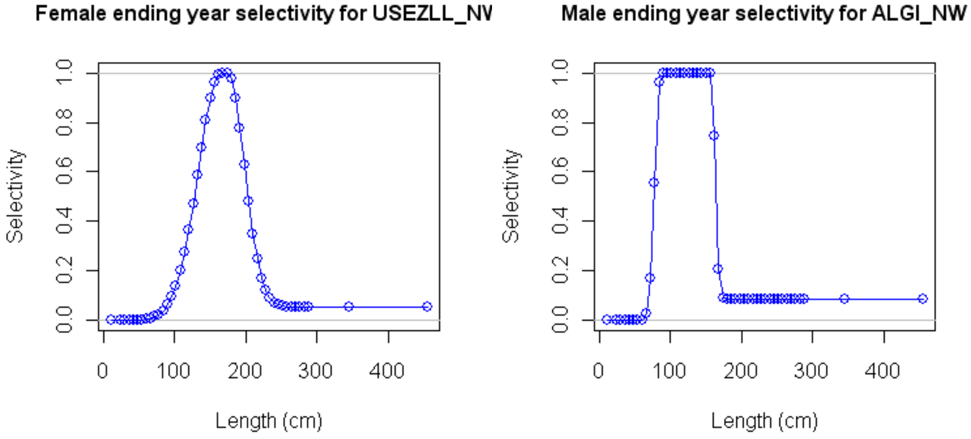

Figure 12. Estimated 'double-normal', length-based selectivity for the longine (left panel) and fillnet (right panel) fleets for aggregate IO model IO-7.

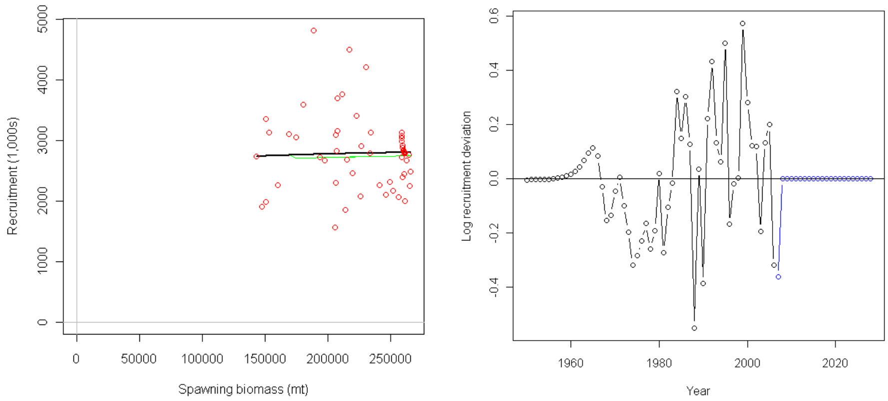

Figure 13. Recruitment dynamics for the aggregate Indian Ocean model IO-7.

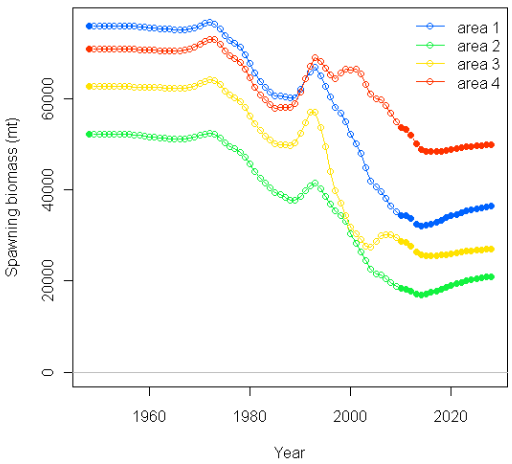

Figure 14. Biomass dynamics by area for the aggregate Indian Ocean model IO-7. Solid points represent 20 years of constant catch projections (at 2008 levels).

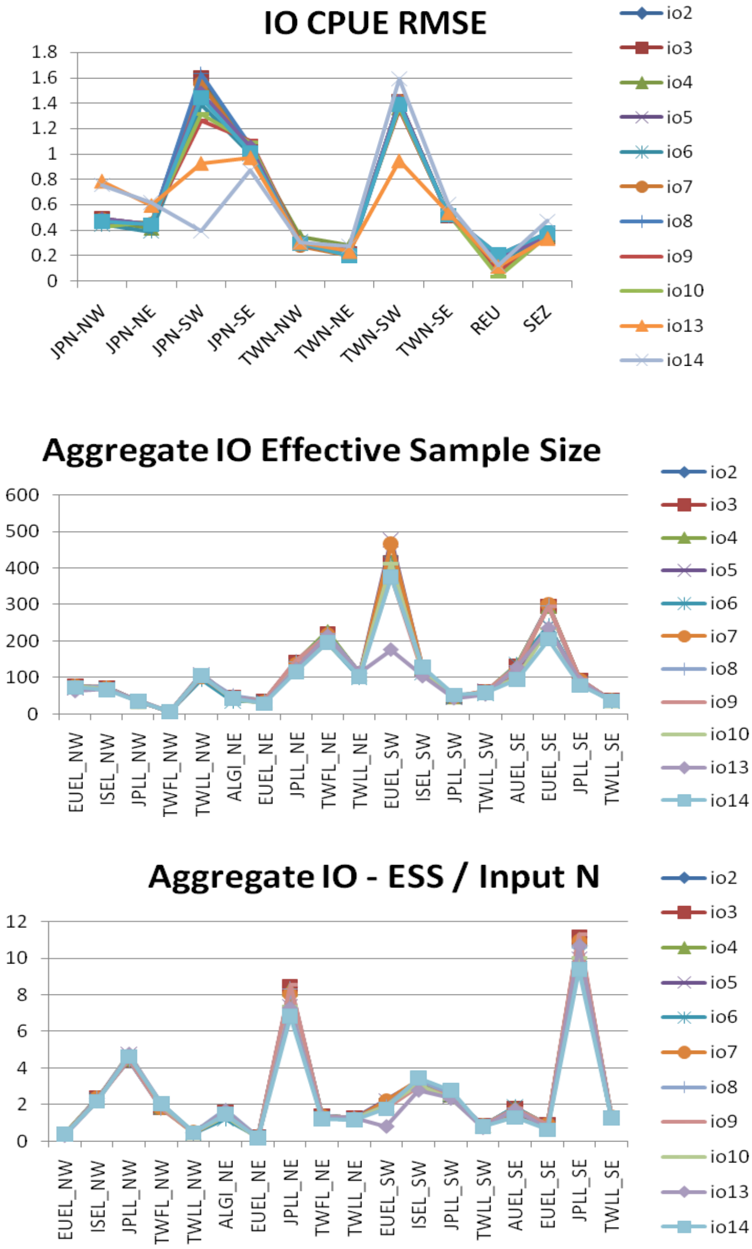

Figure 15. Indicators describing the quality of fit between predicted and observed relative abundance indices (top panel) and size composition data (middle panel). The bottom panel describes the degree of consistency between the size composition assumptions in the model and the quality of fit between predictions and observations (better than expected fit has a ratio >1, and worse than expected fit has a ratio <1).

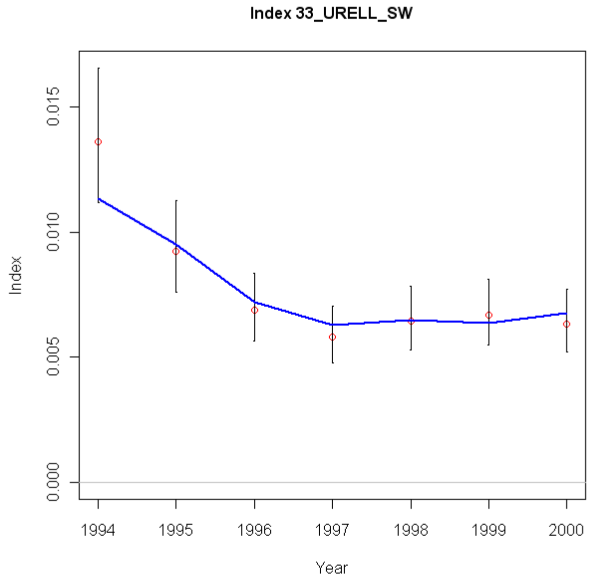

Figure 16. Fit to the REU CPUE series from model IO-9 (with the up-weighted REU CPUE series).

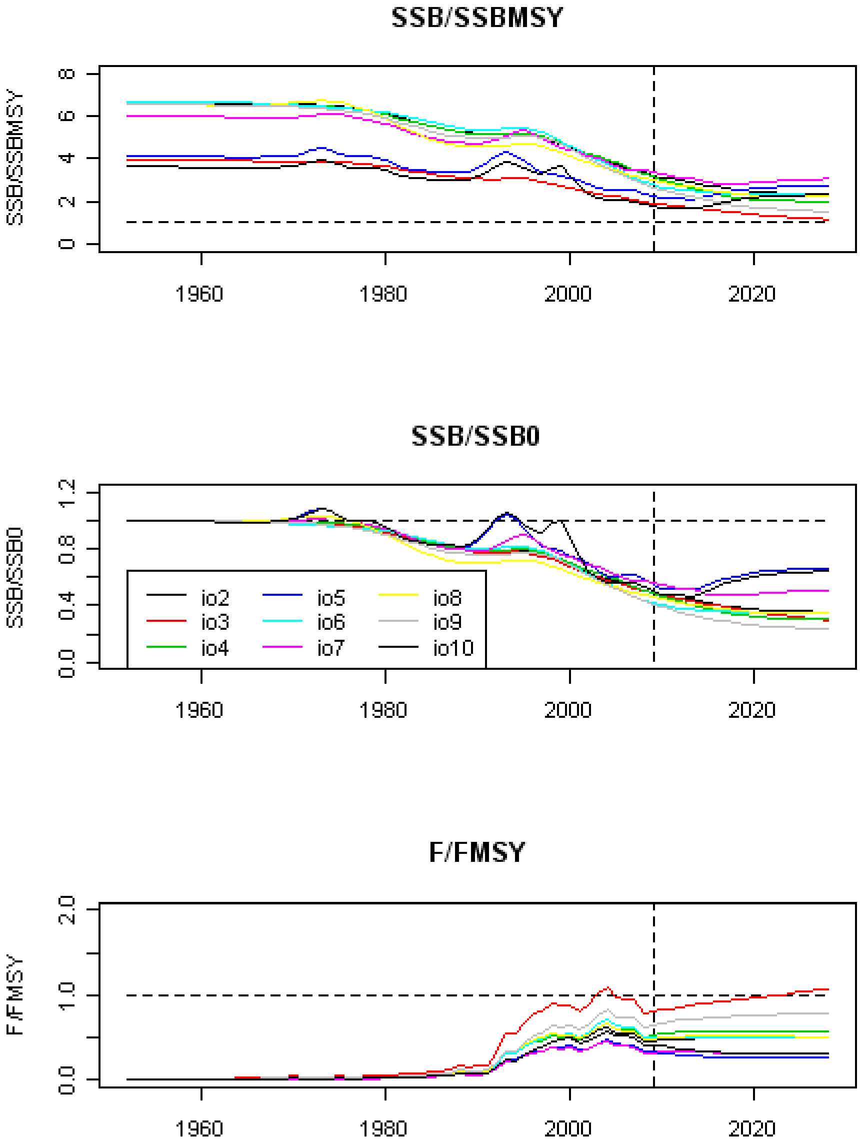

Figure 17. Stock status reference points for the aggregate Indian Ocean models, including 20 years of constant catch projections (Catch=2008 levels).

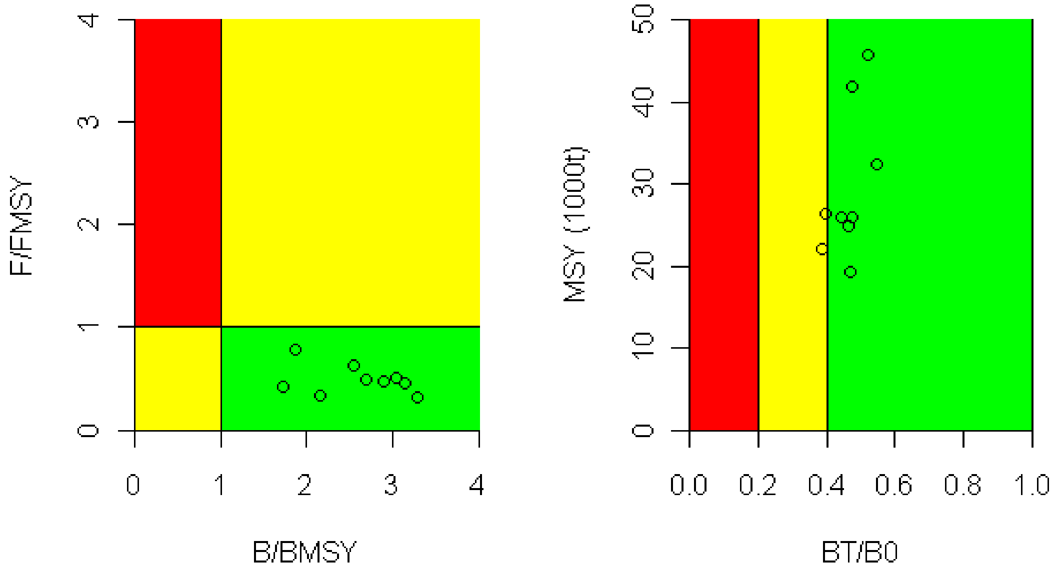

Figure 18. Stock status summary from the 9 aggregate Indian Ocean stock assessment models.

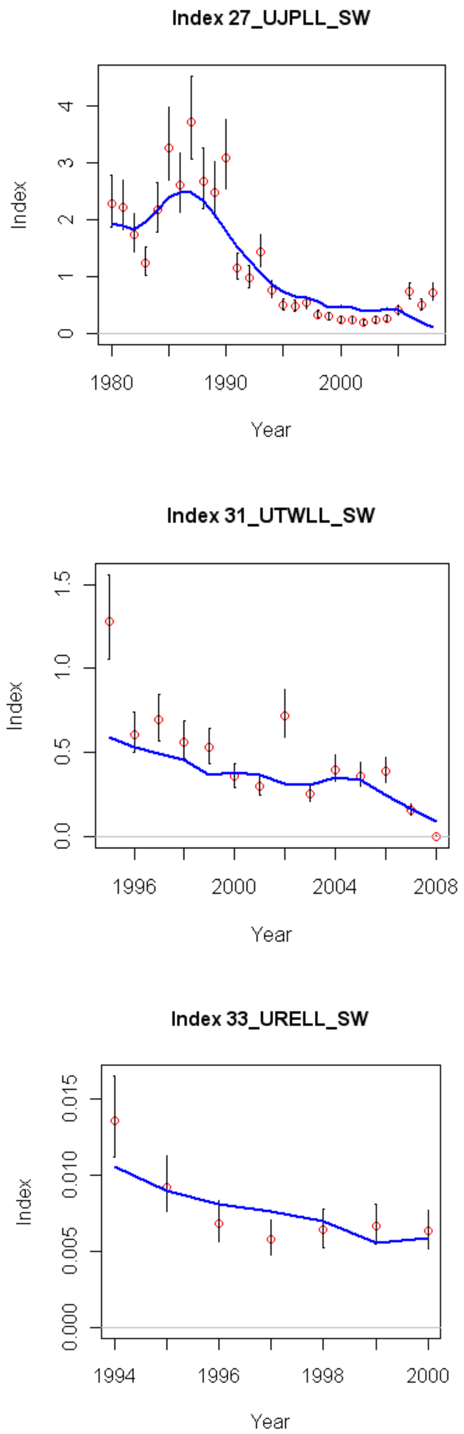

Figure 19. Predicted (line) and observed (circles) CPUE for the JPN, TWN and REU longline fisheries for the SW sub-region model IO-7sw. For graphical purposes, bars indicate the 95% Confidence Intervals for an assumed CV of 10% (which may be subsequently down-weighted depending on the model and series).

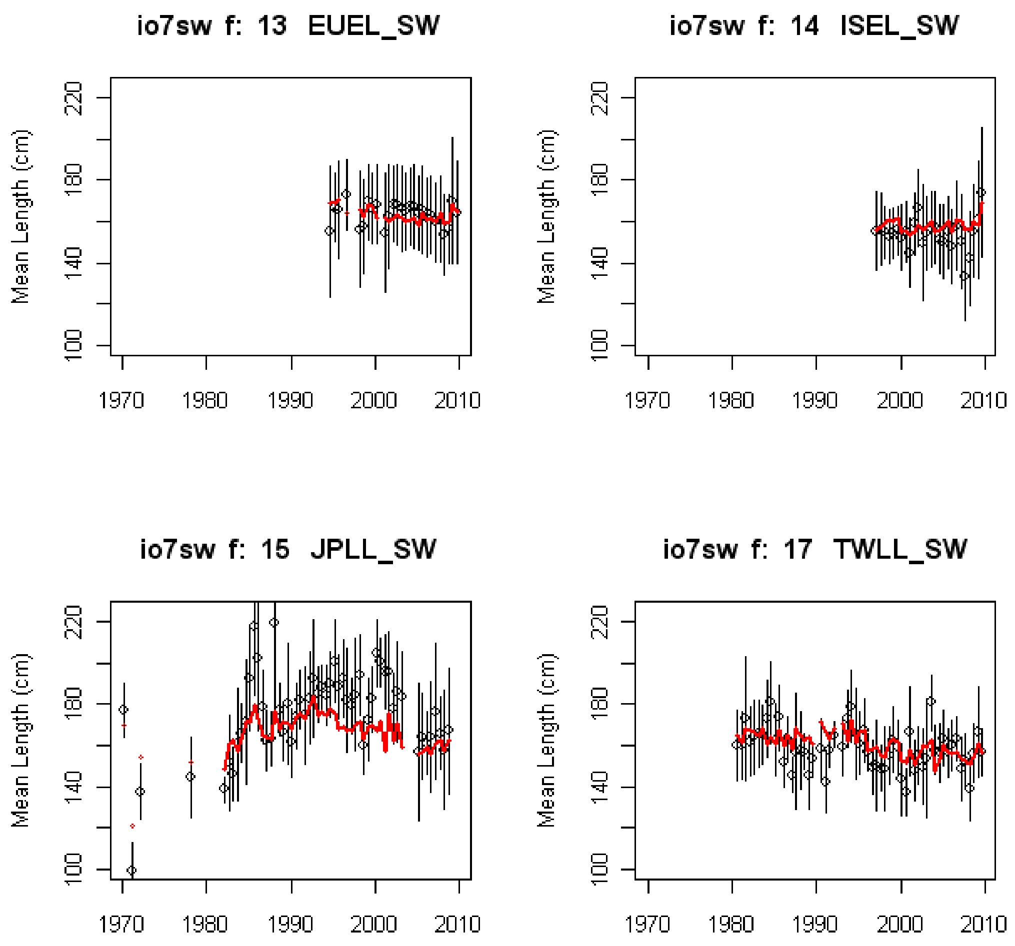

Figure 20. Predicted (red lines) and observed (black circles) mean catch-at-size for each of the 4 SW fleets with size composition data, for the SW sub-region model IO-7sw. Note that the SS3 predicted mean catches are not quite right because only predicted size bins with corresponding observation bins are included in the calculation (i.e. there will be a bias when sample sizes are small).

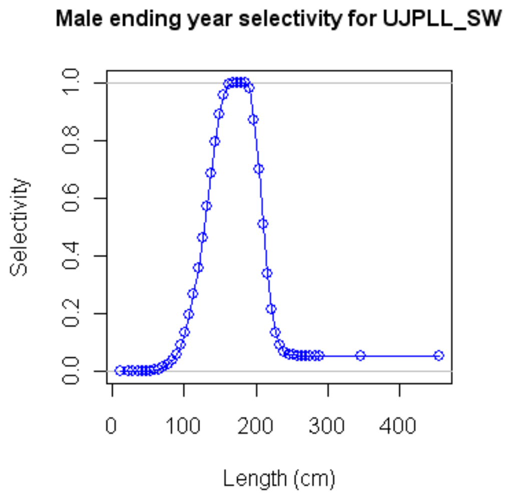

Figure 21. Selectivity estimates for the gillnet and longline selectivities of the SW sub-region model IO-7sw.

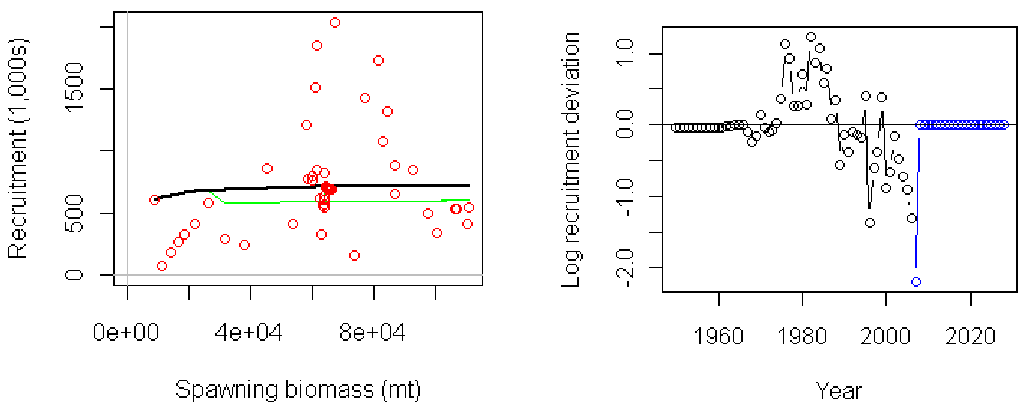

Figure 22. Recruitment dynamics for the SW sub-region model IO-7sw.

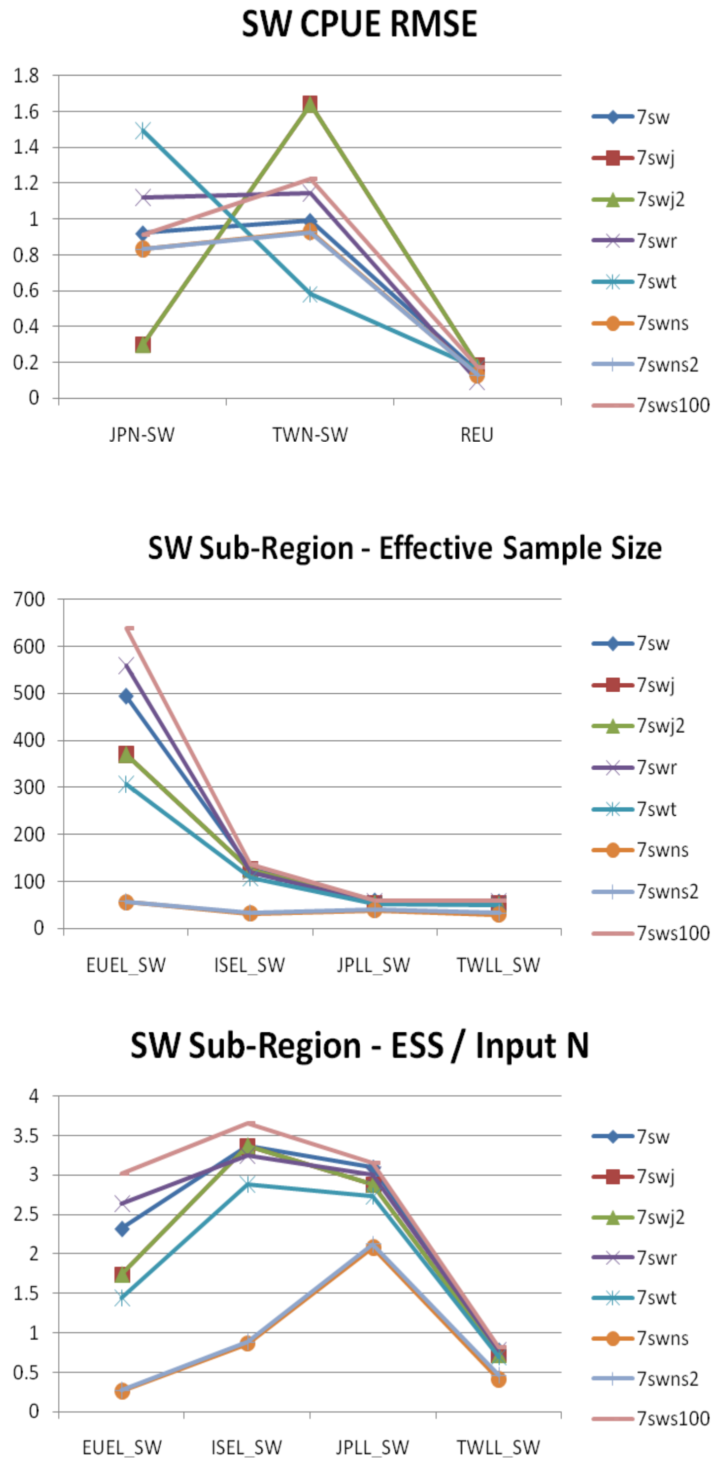

Figure 23. RMSE for the fit to the 3 CPUE series for each of the SW sub-region models.

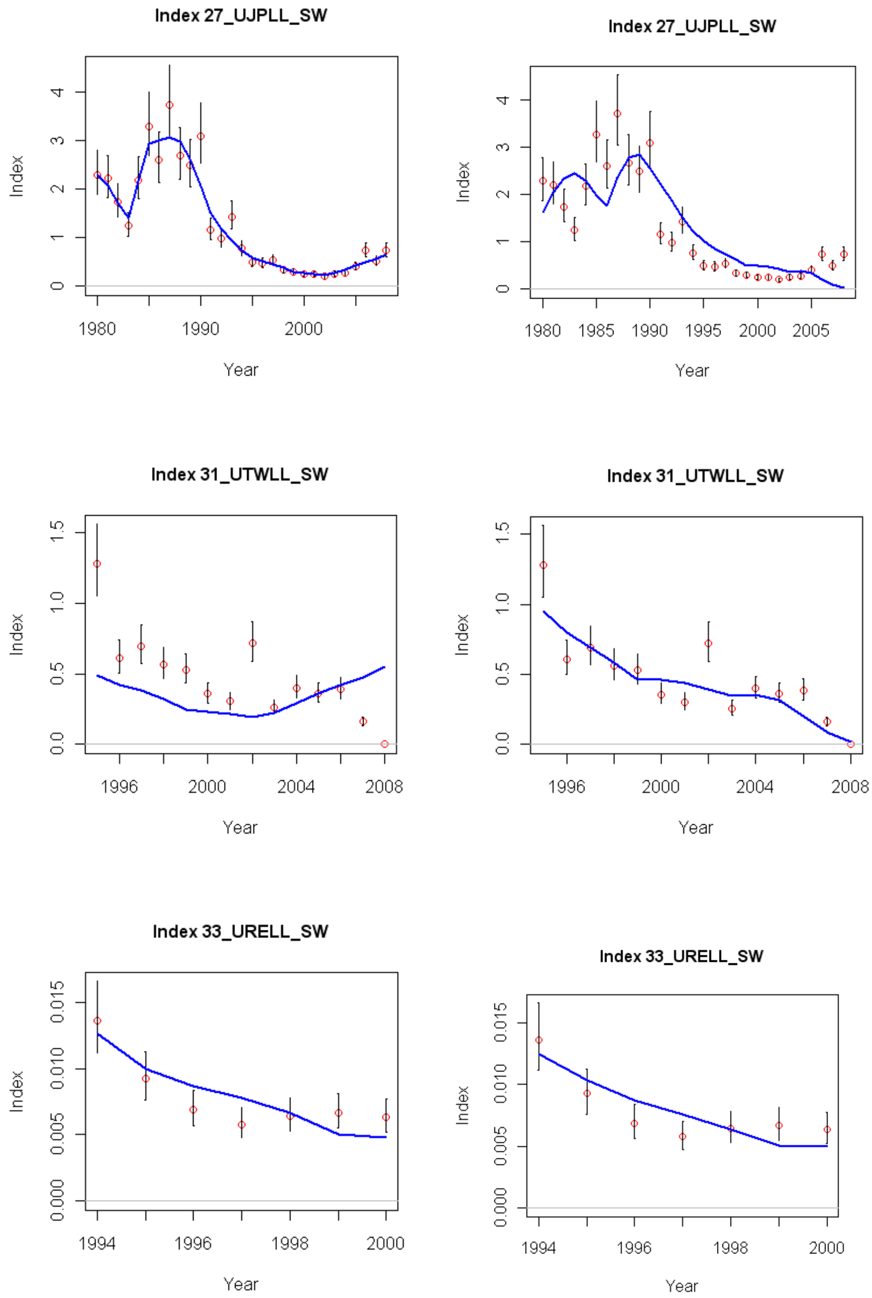

Figure 24. Predicted (line) and observed (circles) CPUE for the JPN, TWN and REU longline fisheries for the SW Sub-region models IO-7swj (JPN CPUE upweighted, left panel) and IO-7swt (TWN CPUE up-weighted, right panel). Bars indicate the 95% Confidence Intervals for an assumed CV of 10% (which may be subsequently down-weighted depending on the model and series).

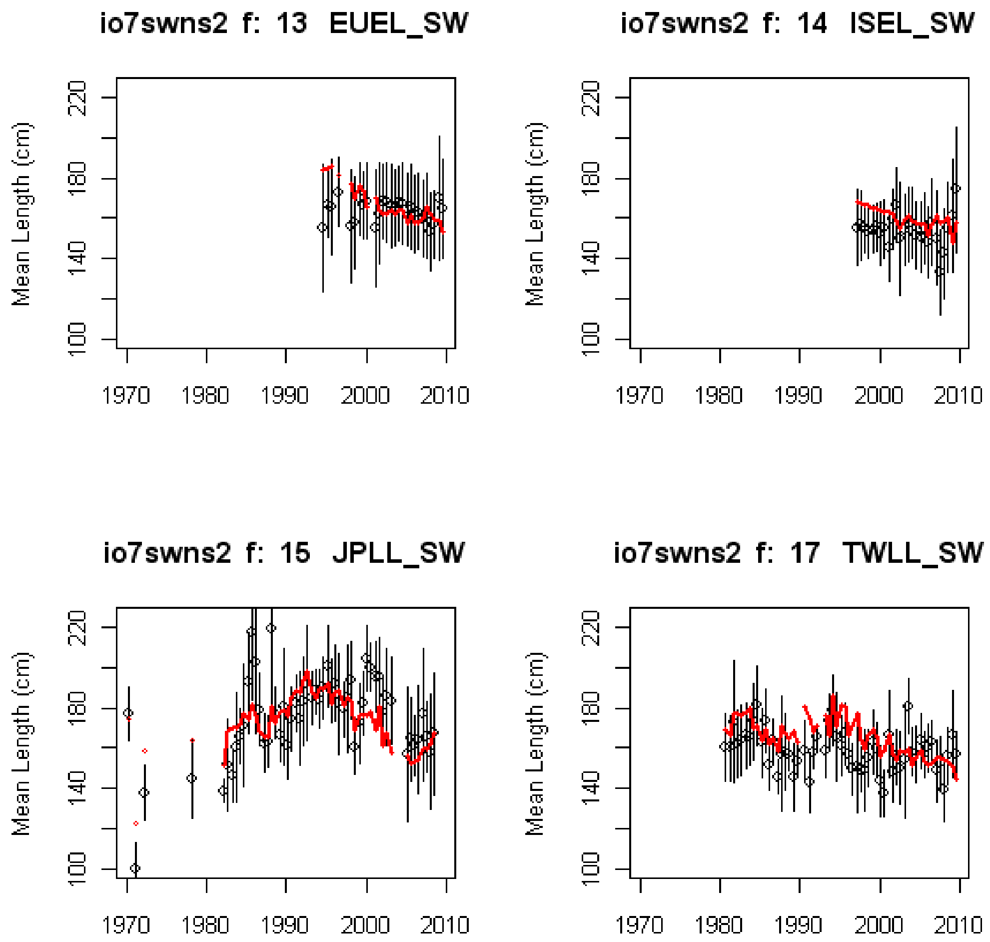

Figure 25. Predicted (red lines) and observed (black circles) mean catch-at-size for each of the 4 SW fleets with size composition data, for the SW sub-region model IO-7swns (size data down-weighted).

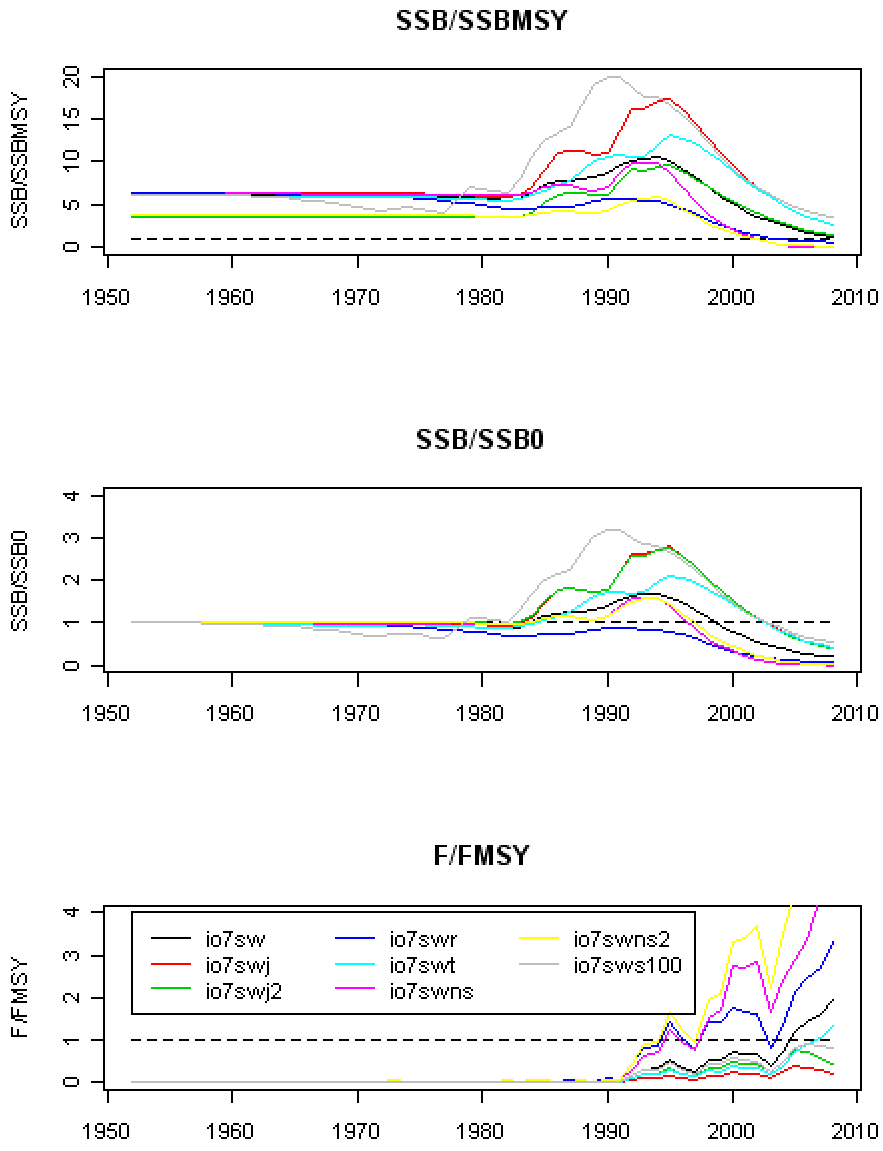

Figure 26. Stock status reference points for the SW sub-region models.

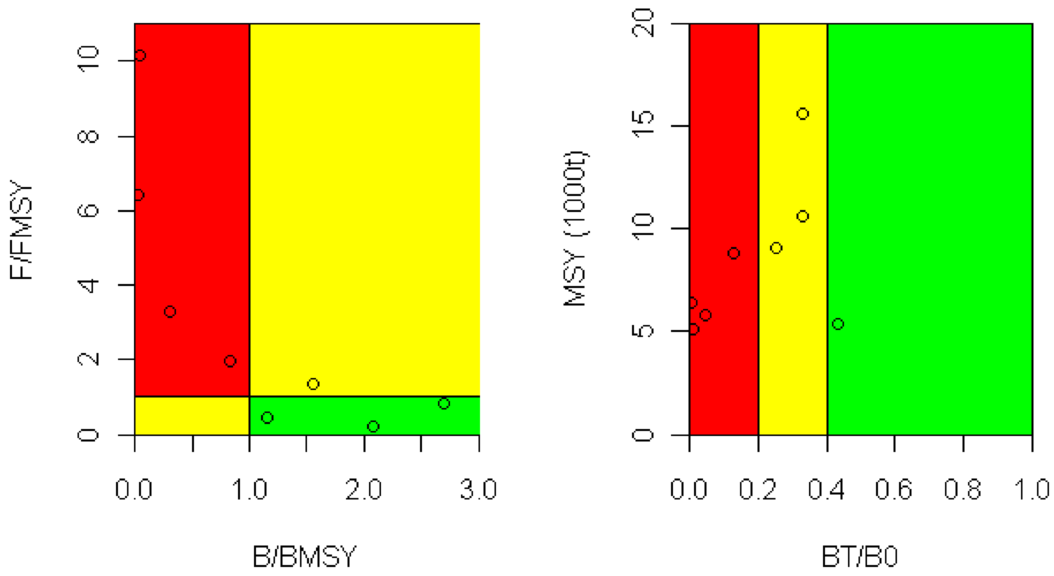

Figure 27. Current stock status summary from the 8 SW sub-region stock assessment models.

Attachment 1. SS3 .ctl file for the reference case specification of the aggregate Indian Ocean model IO-7, indicating prior probability distributions and other parameter specifications not described in the text. Other specification files are archived with the IOTC Secretariat.

```
#_data_and_control_files: NewFeatures3.dat // NewFeatures2.ctl
#_SS-V3.02B;_01/15/09;_Stock_Synthesis_by_Richard_Methot_(NOAA);_using_Otter_Research_ADMB_7.0.1
1  #_N_Growth_Patterns
1 #_N_Morphs_Within_GrowthPattern
#1 #_Morph_between/within_stdev_ratio (no read if N_morphs=1)
# 0.15 0.7 0.15 #vector_Morphdist_(-1_in_first_val_gives_normal_approx)
4 #  number of recruitment assignments (overrides GP*area*seas parameter values)
0 # recruitment interaction requested: 0=none 1=GP*seas*area?
#GP seas area for each recruitment assignment
 1 1 1
 1 1 2
 1 1 3
 1 1 4

8 #_N_movement_definitions
0.6 # first age that moves (real age at begin of season, not integer)
# seas,GP,source_area,dest_area,minage,maxage
 1 1 1 2 39 40
 1 1 1 3 39 40
 1 1 2 1 39 40
 1 1 2 4 39 40
 1 1 3 1 39 40
 1 1 3 4 39 40
 1 1 4 2 39 40
 1 1 4 3 39 40

0 #3 #_Nblock_Patterns
# 3 2 1 #_blocks_per_pattern
# begin and end years of blocks
# 1975 1985 1986 1990 1995 2001
# 1987 1990 1995 2001
# 1999 2000

0.5 #_fracfemale

#1 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
#4 #_N_breakpoints
# 1 4 8 15 # age(real) at M breakpoints

0 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate

#3 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
#M vector - actual values as per MFCL input (maxAge+1)
#0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35
        0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35
        0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35
        0.35   0.35   0.35   0.35   0.35   0.35   0.35
#0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35
        0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35
        0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35
        0.35   0.35   0.35   0.35   0.35   0.35   0.35

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)


#1 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity
#_placeholder for empirical age-maturity by growth pattern

#xxxdk - want maturity option 3 but ain't set up right...seems to want 2 vectors for two sex, two growth morph case
#does this mean one per sex X 2 sexes, or one per morph X 2 female morphs?
3 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity
#CSIRO maturity 50% age 10
#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  0.912807328  0.912807328  0.912807328  0.912807328  0.912807328
0.912807328  0.912807328  0.912807328  0.912807328  0.912807328
#Alternate Maturity 50% age 4
#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      1      1
        1      1      1      1      1      1      1
#Alternate Maturity 50% age 6 (TWN approx)
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      1      1
        1      1      1      1      1      1      1
1 #_First_Mature_Age
1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b


#0
0 # no gender Change
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=with logistic trans to keep within base parm bounds)

#_growth_parms
```

```
#LJ = (6.898 +OF)/0.93 ...length conversion fom Rob Campbell
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
# 0.1 0.7 0.5 0.3 0 1 -7 0 0 0 0 0.5 0 0         # Fem M parm1
  0.1 0.6 0.25 0.25 0 1 8 0 0 0 0 0.5 0 0        # Fem M parm2
# 0.1 0.5 0.3 0.3 0 1 -9 0 0 0 0 0.5 0 0         # Fem M parm3
# 0.1 0.8 0.4 0.3 0 1 -8 0 0 0 0 0.5 0 0         # Fem M parm4
# 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_
# 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_
 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_
 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_
# 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_
 0.24 0.26 0.138 0.138 0 0.1 -3 0 0 0 0 0.5 0 0   # TWN VonBert_K_Fem_GP_1_
#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 0.5 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_

# 0.1 0.7 0.5 0.3 0 1 -7 0 0 0 0 0.5 0 0         # Mal M parm1
  0.1 0.6 0.25 0.25 0 1 8 0 0 0 0 0.5 0 0        # Mal M parm2
# 0.1 0.5 0.3 0.3 0 1 -9 0 0 0 0 0.5 0 0         # Mal M parm3
# 0.1 0.8 0.4 0.3 0 1 -8 0 0 0 0 0.5 0 0         # Mal M parm4
# 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_
# 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_
 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_
 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_
# 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_
 0.26 0.28 0.138 0.138 0 0.1 -3 0 0 0 0 0.5 0 0   # TWN VonBert_K_Mal_GP_1_
# 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 0.5 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 0.5 0 0 # Wtlen1_Fem
 -3 4 3.188 3.188 -1 99 -3 0 0 0 0 0.5 0 0         # Wtlen2_Fem
35     73     55     55     -1     99     -3     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      #      Mat_slope_Fem
-3     3      1      1      -1     99     -3     0     0     0     0     0
       0      0      #      Eg/gm_inter_Fem
-3     3      0      0      -1     99     -3     0     0     0     0     0
       0      0      #      Eg/gm_slope_wt_Fem

 -3 3 3.815e-006 3.815e-006 -1 99 -3 0 0 0 0 0.5 0 0 # Wtlen1_Mal
 -3 4 3.188     3.188     -1 99 -3 0 0 0 0 0.5 0 0 # Wtlen2_Mal
 -8 8 0 1 -1 99 -3 0 0 0 0 0.5 0 0 # RecrDist_GP_1_
 -8 8 0 1 -1 99 -4 0 0 0 0 0.5 0 0 # RecrDist_Area_1_
 -8 8 0 1 -1 99 4 0 0 0 0 0.5 0 0 # RecrDist_Area_2_
 -8 8 0 1 -1 99 4 0 0 0 0 0.5 0 0 # RecrDist_Area_3_
 -8 8 0 1 -1 99 4 0 0 0 0 0.5 0 0 # RecrDist_Area_4_
 -8 8 0 1 -1 99 -7 0 0 0 0 0.5 0 0 # RecrDist_Season_1_
 -8 8 0 1 -1 99 -7 0 0 0 0 0.5 0 0 # RecrDist_Season_2_
 -8 8 0 1 -1 99 -7 0 0 0 0 0.5 0 0 # RecrDist_Season_3_
 -8 8 0 1 -1 99 -7 0 0 0 0 0.5 0 0 # RecrDist_Season_4_
# -1 2 1          1 -1 99          -3 0 0 0 0 0   0 0   # CohortGrowDev
 1 1 1 1 -1 99 -3 0 0 0 0 0 0 0 0 # CohortGrowDev

# -3 ~ 5% move; -1 ~ 37%; -4.6 ~ 1% but check how rescaling works,
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_1_to_2_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_1_to_2_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_1_to_3_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_1_to_3_

 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_2_to_1_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_2_to_1_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_2_to_4_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_2_to_4_

 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_3_to_1_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_3_to_1_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_3_to_4_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_3_to_4_

 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_4_to_2_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_4_to_2_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_A_seas_1__morph_1_from_4_to_3_
 -8 9 -7 -5 0 5 9 0 0 0 0 0 0 0 0 # MoveParm_B_seas_1__morph_1_from_4_to_3_

#_Cond 0  #custom_MG-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-environ parameters

#_custom_MG-block_setup (0/1)
# -2 2 0 0 -1 99 -2 # Wtlen_2_Fem_BLK_1987
# -2 2 0 0 -1 99 -2 # Wtlen_2_Fem_BLK_1995

#_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
# -2 2 0.0002 0 -1 99 -2 # M-WL2_seas_1
# -2 2 -0.0002 0 -1 99 -2 # M-WL2_seas_2

#_Cond -4 #_MGparm_Dev_Phase

#_Spawner-Recruitment
3 #_SR_function
#_LO HI INIT PRIOR PR_type SD PHASE
 7 18 11 11 -1 100 3 # SR_R0
 0.2 1 0.9 0.9 1 0.1 10 # SR_steep
 #0 2 0.5 0.5 -1 0.8 -3 # SR_sigmaR
 0 2 0.2 0.2 -1 0.8 -3 # SR_sigmaR
 -5 5 0.1 0 0 1 -3 # SR_envlink xxxdk - presumably not used
 -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

1 #do_recdev: 0=none; 1=devvector; 2=simple deviations
1950 # first year of main recr_devs; early devs can preceed this era
2006 # last year of main recr_devs; forecast devs start in following year
6 #_recdev phase
1 # (0/1) to read 11 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 prior_fore_recr 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
 1.0   # Max bias adjustment
 0 # future use
 -6 #min rec_dev
 6 #max rec_dev
 0 #_read_recdevs
#_end of advanced SR options

read specified recr devs
#_Yr Input_value

all recruitment deviations
#DisplayOnly 0 # InitAgeComp_21
#DisplayOnly 0 # InitAgeComp_20
#DisplayOnly 0 # InitAgeComp_19
#DisplayOnly 0 # InitAgeComp_18
#DisplayOnly 0 # InitAgeComp_17
#DisplayOnly 0 # InitAgeComp_16
#DisplayOnly 0 # InitAgeComp_15
#DisplayOnly 0 # InitAgeComp_14
#DisplayOnly 0 # InitAgeComp_13
#DisplayOnly 0 # InitAgeComp_12
#DisplayOnly 0 # InitAgeComp_11
#DisplayOnly 0 # InitAgeComp_10
#DisplayOnly 0 # InitAgeComp_9
#DisplayOnly 0 # InitAgeComp_8
#DisplayOnly 0 # InitAgeComp_7
#DisplayOnly 0 # InitAgeComp_6
#DisplayOnly 0 # InitAgeComp_5
#DisplayOnly 0 # InitAgeComp_4
#DisplayOnly 0 # InitAgeComp_3
#DisplayOnly 0 # InitAgeComp_2
#DisplayOnly 0 # InitAgeComp_1
#DisplayOnly 0 # RecrDev_1971
#DisplayOnly 0 # RecrDev_1972
#DisplayOnly 0 # RecrDev_1973
#DisplayOnly 0 # RecrDev_1974
#DisplayOnly 0 # RecrDev_1975
#DisplayOnly 0 # RecrDev_1976
#DisplayOnly 0 # RecrDev_1977
#DisplayOnly 0 # RecrDev_1978
#DisplayOnly 0 # RecrDev_1979
#DisplayOnly 0 # RecrDev_1980
#DisplayOnly 0 # RecrDev_1981
#DisplayOnly 0 # RecrDev_1982
#DisplayOnly 0 # RecrDev_1983
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#DisplayOnly 0 # RecrDev_1998
#DisplayOnly 0 # RecrDev_1999
#DisplayOnly 0 # RecrDev_2000
#DisplayOnly 0 # RecrDev_2001
#DisplayOnly 0 # ForeRecr_2002
#DisplayOnly 0 # ForeRecr_2003
#DisplayOnly 0 # ForeRecr_2004
#DisplayOnly 0 # ForeRecr_2005
#DisplayOnly 0 # ForeRecr_2006
#DisplayOnly 0 # ForeRecr_2007
#DisplayOnly 0 # ForeRecr_2008
#DisplayOnly 0 # ForeRecr_2009
#DisplayOnly 0 # ForeRecr_2010
#DisplayOnly 0 # ForeRecr_2011

#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 # number iterations for 3=hybrid
2.9 # max F or harvest rate, depends on F_Method
no additional F input needed for Fmethod 1
read overall start F value; overall phase; N detailed inputs to read for Fmethod 2
read N iterations for tuning for Fmethod 3 (recommend 3 to 7)
#Fleet Year Seas F_value se phase (for detailed setup of F_Method=2)

```
#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
 0 1 0. 0.01 0 99 -1 # InitF_1?_FISHERY1_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery2_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery3_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery4_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery5_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery6_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery7_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery8_
 0 1 0. 0.01 0 99 -1 # InitF_FISHery9_
 0 1 0. 0.01 0 99 -1 # InitF__FISHery10
 0 1 0. 0.01 0 99 -1 # InitF__FISHery11
 0 1 0. 0.01 0 99 -1 # InitF__FISHery12
 0 1 0. 0.01 0 99 -1 # InitF__FISHery13
 0 1 0. 0.01 0 99 -1 # InitF__FISHery14
 0 1 0. 0.01 0 99 -1 # InitF__FISHery15
 0 1 0. 0.01 0 99 -1 # InitF__FISHery16
 0 1 0. 0.01 0 99 -1 # InitF__FISHery17
 0 1 0. 0.01 0 99 -1 # InitF__FISHery18
 0 1 0. 0.01 0 99 -1 # InitF__FISHery19
 0 1 0. 0.01 0 99 -1 # InitF__FISHery20
 0 1 0. 0.01 0 99 -1 # InitF__FISHery21
 0 1 0. 0.01 0 99 -1 # InitF__FISHery22
 0 1 0. 0.01 0 99 -1 # InitF__FISHery23
 0 1 0. 0.01 0 99 -1 # InitF__FISHery24
# no additional F input needed for Fmethod 1 and 3
# F_method 2 requires:
#Cond 0.05 1 0 #overall start F value; overall phase; N detailed inputs to read
#Fleet Year Seas F_value se phase

#xxxdk one row for each fishery and survey
#    -is Q for missing effort fishery required?
#    - might need to share q across areas for surveys 1-4...
#_Q_setup
 # A=do power, B=env-var, C=extra SD, D=devtype(<0=mirror, 0/1=none, 2=cons, 3=rand, 4=randwalk); E=0=num/1=bio, F=err_type
 #_A  B  C  D  E  F

#xxx order fisheries then surveys...check what happens if 2 replaced by 0...
#  Fisheries
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
# CPUE series
 0 0 0 2 0 0

#shared q=-25 free=2...xxx check sharing is with immediately preceding
# 0 0 0 2 0 0
# 0 0 0 2 0 0
# 0 0 0 2 0 0
 0 0 0 -25 0 0
 0 0 0 -25 0 0
 0 0 0 -25 0 0

 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
 0 0 0 2 0 0
#_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

#order fisheries then CPUE

 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery1_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery2_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery3_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery4_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery5_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery6_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery7_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery8_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery9_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery10_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery11_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery12_
```

```
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery13_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery14_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery15_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery16_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery17_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery18_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery19_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery20_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery21_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery22_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery23_
 -10 10 -0.494066 0 0 99 -1 # Q_base_FISHery24_

#CPUE
 -20 10 -5.0 0 0 99 1 # Q_base_CPUE1_
# comment out below if JPN Q shared
# -20 10 -5.0 0 0 99 1 # Q_base_CPUE2_
# -20 10 -5.0 0 0 99 1 # Q_base_CPUE3_
# -20 10 -5.0 0 0 99 1 # Q_base_CPUE4_

 -20 10 -5.0 0 0 99 1 # Q_base_CPUE5_
# comment out below if TWN Q shared
 -20 10 -5.0 0 0 99 1 # Q_base_CPUE6_
 -20 10 -5.0 0 0 99 1 # Q_base_CPUE7_
 -20 10 -5.0 0 0 99 1 # Q_base_CPUE8_

 -20 10 -5.0 0 0 99 1 # Q_base_CPUE9_
 -20 10 -5.0 0 0 99 1 # Q_base_CPUE10_



#_size_selex_types ALGI_NE
#_Pattern Discard Male Special
24 0 0 0   #ALGI_NW  f1      noSizeData but shared with other gillnets
24 0 0 0   #EUEL_NW  f2
5 0 0 2   #ISEL_NW  f3
5 0 0 2   #JPLL_NW  f4
5 0 0 2   #TWFL_NW  f5
5 0 0 2   #TWLL_NW  f6
5 0 0  1   #ALGI_NE  f7
5 0 0 2   #EUEL_NE  f8   #sometimes estimated f8 estimated independently
5 0 0 2    #JPLL_NE  f9
5 0 0 2   #TWFL_NE  f10
5 0 0 2   #TWLL_NE  f11
5 0 0  1   #ALGI_SW  f12
5 0 0 2    #EUEL_SW  f13
5 0 0 2    #ISEL_SW  f14
5 0 0 2   #JPLL_SW  f15
5 0 0 2   #TWFL_SW  f16
5 0 0 2   #TWLL_SW  f17
5 0 0  1   #ALGI_SE  f18
5 0 0 2   #AUEL_SE  f19
5 0 0 2   #EUEL_SE  f20
5 0 0 2   #ISEL_SE  f21
5 0 0 2   #JPLL_SE  f22
5 0 0 2   #TWFL_SE  f23
5 0 0 2   #TWLL_SE  f24

5 0 0 2  #UJPLL_NW cpue1
5 0 0 2   #UJPLL_NE cpue2
5 0 0 2   #UJPLL_SW cpue3
5 0 0 2   #UJPLL_SE cpue4
5 0 0 2   #UTWLL_NW cpue5
5 0 0 2   #UTWLL_NE cpue6
5 0 0 2   #UTWLL_SW cpue7
5 0 0 2   #UTWLL_SE cpue8
5 0 0 2   #URELL_SE cpue9
5 0 0 2   #USEZLL_SE cpue10


#_size_selex_types
#_Pattern Discard Male Special#_age_selex_types
# 0 0 0 0 # cpue1#dkxxx -check distinction between fleets and surveys...and sharing sel across them
# 0 0 0 0 # cpue2
# 0 0 0 0 # cpue3
# 0 0 0 0 # cpue4

# 0 0 0 0 #   f1
# 0 0 0 0 #   f2
# 0 0 0 0 #   f3
# 0 0 0 0 #   f4
# 0 0 0 0 #   f5
# 0 0 0 0 #   f6
# 0 0 0 0 #   f7
# 0 0 0 0 #   f8
# 0 0 0 0 #   f9
# 0 0 0 0 #   f10
# 0 0 0 0 #   f11
# 0 0 0 0 #   f12
# 0 0 0 0 #   f13
# 0 0 0 0 #   f14
# 0 0 0 0 #   f15
# 0 0 0 0 #   f16
# 0 0 0 0 #   f17
# 0 0 0 0 #   f18
# 0 0 0 0 #   f19
# 0 0 0 0 #   f20
# 0 0 0 0 #   f21
# 0 0 0 0 #  f22
# 0 0 0 0 # f23
# 0 0 0 0 # f24
```

```
#_age_selex_types
# 17 0 0 0 # cpue1
# 15 0 0 1 # cpue2  mirror f1
# 15 0 0 1 # cpue3
# 15 0 0 1 # cpue4
# 15 0 0 1 # f1
# 15 0 0 1 # f2
# 15 0 0 1 # f3
# 15 0 0 1 # f4
# 15 0 0 1 # f5
# 15 0 0 1 # f6
# 15 0 0 1 # f7
# 15 0 0 1 # f8
# 15 0 0 1 # f9
# 15 0 0 1 # f10
# 15 0 0 1 # f11
# 15 0 0 1 # f12
# 15 0 0 1 # f13
# 15 0 0 1 # f14
# 15 0 0 1 # f15
# 15 0 0 1 # f16
#15 0 0 1 # f17
#15 0 0 1 # f18
#15 0 0 1 # f19
#15 0 0 1 # f20
#15 0 0 1 # f21
#15 0 0 1 # f22
#15 0 0 1 # f23
#15 0 0 1 # f24
#
#_age_selex_types = none
10 0 0 0 # f1
10 0 0 0 # f2
10 0 0 0 # f3
10 0 0 0 # f4
10 0 0 0 # f5
10 0 0 0 # f6
10 0 0 0 # f7
10 0 0 0 # f8
10 0 0 0 # f9
10 0 0 0 # f10
10 0 0 0 # f11
10 0 0 0 # f12
10 0 0 0 # f13
10 0 0 0 # f14
10 0 0 0 # f15
10 0 0 0 # f16
10 0 0 0 # f17
10 0 0 0 # f18
10 0 0 0 # f19
10 0 0 0 # f20
10 0 0 0 # f21
10 0 0 0 # f22
10 0 0 0 # f23
10 0 0 0 # f24

10 0 0 0 # cpue1#dkxxx -check distinction between fleets and surveys...and sharing sel across them
10 0 0 0 # cpue2
10 0 0 0 # cpue3
10 0 0 0 # cpue4
10 0 0 0 # cpue5
10 0 0 0 # cpue6
10 0 0 0 # cpue7
10 0 0 0 # cpue8
10 0 0 0 # cpue9
10 0 0 0 # cpue10


#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
#dkxxx - 17 = age-specific parms parameterized as nd walk form previous
#      - recommended to fix first sel parm
#      - later ones tightly constrained
#double normal for fishery 1
# LO HI INIT PRIOR PR_type SD PHASE
50 200 150 150  1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_1_f1 and all LL and cpue except EUEL_NE, f=8
-6 4 -3    -3   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_2_all LL and cpue
-1 9 8.3   8.3  1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_3_
-1 9 4      4   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_4_
-15 -5 -10 -1   1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_5_
-5 9 1.7   -1   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_6_

50 200 150 150  1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_1_f2 and all GN and miscellaneous
-6 4 -3    -3   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_2_
-1 9 8.3   8.3  1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_3_
-1 9 4      4   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_4_
-15 -5 -10 -1   1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_5_
-5 9 1.7   -1   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_6_


-5 3 1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f3
-5 3 -1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f3

-5 3 1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f4
-5 3 -1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f4

-5 3 1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f5
-5 3 -1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f5

-5 3 1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f6
-5 3 -1 -4     1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f6
```

```
-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f7
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f7

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f8
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f8

#50 200 150 150  1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_1_f8 EUEL_NE which looks like small fish
#-6 4 -3    -3   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_2_
#-1 9 8.3   8.3  1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_3_
#-1 9 4     4   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_4_
#-15 -5 -10 -1   1 99 -3 0 0 0 0 0.5 0 0 # SizeSel_1P_5_
#-5 9 1.7   -1   1 99 3  0 0 0 0 0.5 0 0 # SizeSel_1P_6_

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f9
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f9

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f10
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f10

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f11
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f11

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f12
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f12

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f13
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f13

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f14
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f14

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f15
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f15

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f16
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f16

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f17
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f17

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f18
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f18

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f19
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f19

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f20
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f20

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f21
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f21

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f22
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f22

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f23
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f23

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 f24
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 f24


-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue1
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue1

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue2
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue2

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue3
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue3

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue4
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue4

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue5
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue5

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue6
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue6

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue7
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue7

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue8
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue8

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue9
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue9

-5 3 1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p1 cpue10
-5 3 -1 -4    1 0.05 -3 0 0 0 0 0.5 0 0 # size sel mirror p2 cpue10


#length bin indicators for mirror fisheries
#documentation not exactly clear on expectations here
#presumably these would never be estimated, so why are they parms?
#these are embedded in sequece above with estimated parms

#  -9 5 -8 -8 0 99. -3 0 0 0 0 0.5 0 0 # AgeSel_1_P_1__FISHERY1_
```

```
#  -9 5 0 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_2__FISHERY1_
#  -9 5 0 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_3__FISHERY1_
#  -9 5 1 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_4__FISHERY1_
#  -9 5 1 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_5__FISHERY1_
#  -9 5 0 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_6__FISHERY1_
#  -9 5 0 0 0 0.1 6 0 0 0 0 0.5 0 0 # AgeSel_1_P_7__FISHERY1_
#  -9 5 0 0 0 0.1 6 0 0 0 0 0.5 0 0 # AgeSel_1_P_8__FISHERY1_
#  -9 5 0 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_9__FISHERY1_
#  -9 5 0 0 0 0.1 6 0 0 0 0 0.5 0 0 # AgeSel_1_P_10__FISHERY1_
#  -9 5 0 0 0 0.1 6 0 0 0 0 0.5 0 0 # AgeSel_1_P_11__FISHERY1_
#  -9 5 0 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_12__FISHERY1_
#  -9 5 0 0 0 0.1 6 0 0 0 0 0.5 0 0 # AgeSel_1_P_13__FISHERY1_
#  -9 5 0 0 0 0.1 6 0 0 0 0 0.5 0 0 # AgeSel_1_P_14__FISHERY1_
#  -9 5 0 0 0 0.1 6 0 0 0 0 0.5 0 0 # AgeSel_1_P_15__FISHERY1_
#  -9 5 0 0 0 0.1 3 0 0 0 0 0.5 0 0 # AgeSel_1_P_16__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_17__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_18__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_19__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_20__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_21__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_22__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_23__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_24__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_25__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_26__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_27__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_28__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_29__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_30__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_31__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_32__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_33__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_34__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_35__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_36__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_37__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_38__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_39__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_40__FISHERY1_
#  -9 5 0 0 0 0.1 -6 0 0 0 0 0.5 0 0 # AgeSel_1_P_41__FISHERY1_


# 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

0 #_Variance_adjustments_to_input_values
#_1 2 3 4
#_Cond  0 0 0 0 #_add_to_survey_CV
#_Cond  0 0 0 0 #_add_to_discard_stddev
#_Cond  0 0 0 0 #_add_to_bodywt_CV
#_Cond  1 1 1 1 #_mult_by_lencomp_N
#_Cond  1 1 1 1 #_mult_by_agecomp_N
#_Cond  1 1 1 1 #_mult_by_size-at-age_N
30 #_DF_for_discard_like
30 #_DF_for_meanbodywt_like

4 #_maxlambdaphase
1 #_sd_offset

68 # number of changes to make to default Lambdas (default value is 1.0)
# Like_comp codes:  1=survey; 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
#like_comp fleet/survey  phase  value  sizefreq_method

 1 25 1 1 1
 1 26 1 1 1
 1 27 1 0.00001 1
 1 28 1 0.1 1

 1 29 1 1 1
 1 30 1 1 1
 1 31 1 0.00001 1
 1 32 1 0.1 1

 1 33 1 1 1
 1 34 1 0.00001 1

 4 1 1 0.001 1
 4 2 1 0.001 1
 4 3 1 0.001 1
 4 4 1 0.001 1
 4 5 1 0.001 1
 4 6 1 0.001 1
 4 7 1 0.001 1
 4 8 1 0.001 1
 4 9 1 0.001 1
 4 10 1 0.001 1
 4 11 1 0.001 1
 4 12 1 0.001 1
 4 13 1 0.001 1
 4 14 1 0.001 1
 4 15 1 0.001 1
 4 16 1 0.001 1
 4 17 1 0.001 1
 4 18 1 0.001 1
 4 19 1 0.001 1
 4 20 1 0.001 1
 4 21 1 0.001 1
 4 22 1 0.001 1
```

```
 4 23 1 0.001 1
 4 24 1 0.001 1

 1 25 4 1.0 1
 1 26 4 1.0 1
 1 27 4 0.00001 1
 1 28 4 0.1 1
 1 29 4 1.0 1
 1 30 4 1.0 1
 1 31 4 0.00001 1
 1 32 4 0.1 1
 1 33 1 1.0 1
 1 34 1 0.00001 1

 4 1 4 1.0 1
 4 2 4 1.0 1
 4 3 4 1.0 1
 4 4 4 1.0 1
 4 5 4 1.0 1
 4 6 4 1.0 1
 4 7 4 1.0 1
 4 8 4 1.0 1
 4 9 4 1.0 1
 4 10 4 1.0 1
 4 11 4 1.0 1
 4 12 4 1.0 1
 4 13 4 1.0 1
 4 14 4 1.0 1
 4 15 4 1.0 1
 4 16 4 1.0 1
 4 17 4 1.0 1
 4 18 4 1.0 1
 4 19 4 1.0 1
 4 20 4 1.0   1
 4 21 4 1.0 1
 4 22 4 1.0 1
 4 23 4 1.0 1
 4 24 4 1.0 1


#like_comp fleet/survey  phase  value  sizefreq_method
# 1 1 1 0.0001 1

# lambdas (for info only; columns are phases)
#  1 1 1 #_CPUE/survey:_1
#  0 0 0 #_CPUE/survey:_2
#  1 1 1 #_CPUE/survey:_3
#  1 1 1 #_CPUE/survey:_4
#  1 1 1 #_discard:_1
#  0 0 0 #_discard:_2
#  0 0 0 #_discard:_3
#  0 0 0 #_discard:_4
#  1 1 1 #_meanbodywt:1
#  1 1 1 #_meanbodywt:2
#  1 1 1 #_meanbodywt:3
#  1 1 1 #_meanbodywt:4
#  1 1 1 #_lencomp:_1
#  0 0 0 #_lencomp:_2
#  1 1 1 #_lencomp:_3
#  0 0 0 #_lencomp:_4
#  1 1 1 #_agecomp:_1
#  0 0 0 #_agecomp:_2
#  1 1 1 #_agecomp:_3
#  0 0 0 #_agecomp:_4
#  1 0.7 0.7 #_sizefreq:_1
#  1 1 1 #_sizefreq:_2
#  1 1 1 #_size-age:_1
#  1 1 1 #_size-age:_2
#  0 0 0 #_size-age:_3
#  0 0 0 #_size-age:_4
#  1 1 1 #_init_equ_catch
#  1 1 1 #_recruitments
#  1 1 1 #_parameter-priors
#  1 1 1 #_parameter-dev-vectors
#  1 1 1 #_crashPenLambda
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
 # placeholder for vector of selex bins to be reported
 # placeholder for vector of growth ages to be reported
 # placeholder for vector of natage ages to be reported
999
```