SCIENTIFIC COMMITTEE
TWELFTH REGULAR SESSION

Bali, Indonesia
3-11 August 2016

Stock Assessment for south Pacific albacore tuna using stock synthesis

WCPFC-SC12-2016/ SA-IP-18

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Summary

This paper presents the assessment of south Pacific albacore tuna using Stock Synthesis model (SS3). The data sets used in this assessment (1960-2013), including catch (14 fisheries), abundance indices (standardized CPUE), and length composition, are the same as those used in assessment with MULTIFAN-CL in 2015. However, no spatial structure was modeled in the current SS3 model. The assessment results from the current SS3 model run are similar to those from the MULTIFAN-CL. The total biomass and spawning potential have the same temporal trend, demonstrating a declining trend over the time period, except for peaks in the mid-1970s and around 2000. The base-case model (natural mortality=0.3 per year and steepness=0.8 for the B-H spanwer-recruit relationship) results in an MSY estimate of 77,948 mt. The spawning potential that would support the MSY is estimated to be 29% of virgin spawning potential. Current fishing mortality is estimated to be less than the level that would produce MSY. Current biomass is estimated to be higher than the level that would support the MSY.

Introduction

The methodology used regularly for the assessment of south Pacific albacore tuna (*Thunnus alalunga*) is known as MULTIFAN-CL, which is an integrated size-based, age- and spatially-structured assessment model (Harley et al., 2015). However, the assessment and management of this stock would benefit from exploring alternative models for confirmatory analysis. This paper presents the stock assessment of south Pacific albacore tuna using stock synthesis (Methot and Wetzel, 2012). This assessment report should not be seen as a standalone document and should be read in conjunction with other previous working papers; specifically, this assessment is supported by the assessment report 2015 (Harley et al., 2015) to which the SS3 input data and configurations are identical or similar.

Data compilation

Data used in this assessment consist of fishery-specific catch, CPUE and length-frequency data, which are identical to those used in Harley et al. (2015). The time period covered by this assessment is the first season of 1960 to the final season of 2013. Data were aggregated into seasons (Jan – Mar, Apr – Jun, Jul – Sep, and Oct – Dec). Gear type, fishing method and spatial location are used to defined the fisheries, which resulted in 14 fisheries for this assessment. Catch and effort data were aggregated based on these 14 fisheries. All catches were expressed in numbers of fish, with the exception of the driftnet fishery (catches in weight, metric tonnes). Effort of longline fisheries was standardized, whereas for troll and driftnet fisheries effort was defined as the number of vessel days of fishing activity. The CPUE indices were standardized before they were input to the assessment model. Full details could be found in Tremblay-Boyer et al. (2015a, b). Available length composition data for each of the defined fisheries (from MULTIFAN-CL input) were compiled into 20, 5-cm size classes (30-125cm).

Model description

The detailed model technical descriptions can be found in Methot (2013), and are not repeated here. The stock synthesis modeling framework is highly flexible and can be applied to a wide variety of situations, from data-weak situations to complex situations. Here we summarize how the model was configured for south Pacific albacore tuna for each of the model components.

Population dynamics

The population was partitioned into 12 age classes and modeled at quarterly time step through a time period of 1960 – 2013. Unlike Harley et al. (2015) where spatial structure is accounted for in the model, the assessment presented here does not incorporate spatial structured explicitly due to the uncertainty associated with the conversion of tagging data.

Albacore recruitment was assumed to be a quarterly event that occurs at the beginning of each season. Annual recruitment was assumed to be related to spawning stock biomass according to the Beverton-Holt stock-recruitment relationship. This annual recruitment was distributed among seasons according to the model parameters (i.e., seasonal proportions). These proportion parameters were activated to be estimated in the model. As in the assessment conducted using MULTIFAN-CL, the steepness coefficient parameter h of the B-H model was fixed at the value of 0.8. However, alternative values of 0.65 and 0.95 were considered as part of the sensitivity analyses. Growth was assumed to follow a von Bertalanffy growth curve. The parameters were fixed in the model at the values estimated from Harley et al. (2015).

Natural mortality was assumed to be constant across ages and over years. It was fixed at 0.3 in this assessment to be consistent with Harley et al. (2015). However, the uncertainty associated with natural mortality was evaluated through sensitivity analysis where alternative values of 0.25 and 0.4 were examined. The maturity-at-age and weight-at-age were also assumed to be time-invariant and were taken from Harley et al. (2015).

Fishery dynamics

Selectivity in the model was specified as fishery-specific and assumed to be time-invariant and size-based. The selectivities were estimated using double normal parameterization. Each selectivity function was parameterized with six parameters, allowing the selectivity pattern to be dome-shaped or asymptotic. Catchability was assumed to be constant over time for all longline fisheries due to the standardized CPUE indices from which effort was derived. For other fisheries, the catchability was allowed to vary over time, which was modeled as a random walk.

Likelihood components and parameter estimation

There are three data components that contribute to the objective function: the total catch data, the standardized CPUE data, and the size composition data. The parameters of the model were estimated by maximizing the log-likelihoods of the data plus the log of the probability density function of the priors and including some penalties specified in the model. A variance-covariance matrix (i.e., Hessian calculation) was calculated to represent uncertainty in the estimates. The uncertainty in the derived quantities (e.g., spawning biomass, stock depletion, and various reference points) was calculated using Taylor series approximation.

Reference points

Both MSY- and SPR-based reference points were calculated, such as SPR at F intensity that produces a specified SSB target, F statistic at F intensity that produces a specified SSB target, total yield at F intensity that produces a specified SSB target, SSB at a specified SPR target (taking into account the stock recruitment relationship), F intensity that produces a specified SPR target, SSB at F intensity that is associated with MSY, SPR at F intensity associated with MSY, F statistic at F intensity associated with MSY, and total yield at MSY. Also, some additional quantities were calculated, e.g., unfished reproductive potential, unfished recruitment.

Sensitivity and retrospective analyses

Model sensitivity to natural mortality and steepness parameters were evaluated through sensitivity analyses. For natural mortality we assumed a value of 0.3 per year for the base case and examined the values of 0.25 and 0.4. For steepness we assumed a value of 0.8 for the base case, but examined the values of 0.65 and 0.95. The number of model runs for structural uncertainty analysis is limited in this paper due to the limited time we have for this work and time consuming estimation process (approximately 1hr for a single model run). Retrospective analysis with 8 peels was conducted to evaluate if there are potential misspecifications in the assessment model.

Model results and diagnostics (base case)

The fit of the model to the catch data was acceptable (Figures 2 and 3). The fit to the standardized CPUE indices is shown in Figures 7 – 14. The aggregated (across all observations for a fishery) observed and predicted length composition for each fishery is presented to illustrate the fit to the observed size composition data (Figure 15), which appears satisfactory. Length-specific selectivity is shown in Figure 16.

The estimated annual recruitment and its uncertainty are shown in Figure 19. The recruitments exhibit large temporal variation over the time period. Trends in biomass are represented using the total biomass (Figure 17), as well as spawning potential (Figure 18). The total biomass and spawning potential have the same temporal trend, demonstrating a nearly constant decline over the time period, except for peaks in the mid-1970s and around 2000. The spawning potential and depletion show that the current spawning biomass is at its lowest historical level (depleted about 40%). The estimated fishing mortality rates increased throughout the time series and are currently at their highest level.
MSY is estimated at 77948 mt, which is very close to the estimate from the MULTIFAN-CL model, i.e., 76800 mt (Harley et al., 2015). The spawning potential that would support the *MSY* is estimated to be 29% of virgin spawning potential.

Conclusion and discussion

- Current fishing mortality is estimated to be less than the fishing mortality that would produce *MSY* (Figure 25)
- Recent biomass is estimated to be higher than the biomass that would support the *MSY* (Figure 25).

The assessment results from the current SS3 model run were similar to those from the MULTIFAN-CL. However, the base run presented here did not incorporate spatial structure. The reasons that prevent us from setting up spatial model are: 1) the amount of time necessary to complete a single run of this type if assessment, it light of its purpose as a baseline for this type of assessment moving forward; 2) the large uncertainty associated with converting tagging data from MULTIFAN-CL.

The assessment model was difficult to converge in the sensitivity and retrospective analysis. Therefore, the figures for sensitivity and retrospective analysis were not included in this paper. Based on the converged model runs, the assessment results were sensitive to the removal of data and steepness.

Acknowledgment: We thank Dr. Yukio Takeuchi for providing R codes for transferring Multifan-cl based data sets to data sets used by SS3. The work was supported by the Project of GaoFeng Discipline of Fishery Science and International Center for Marine Studies at Shanghai Ocean University.

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Tremblay-Boyer, L., McKechnie, S., and Harley, S. J. (2015b). Standardized CPUE for south Pacific albacore tuna (*Thunnus alalunga*) from operational longline data. WCPFC-SC11-2015/SA-IP-03, Pohnpei, Federated States of Micronesia, 5 – 13 August 2015.

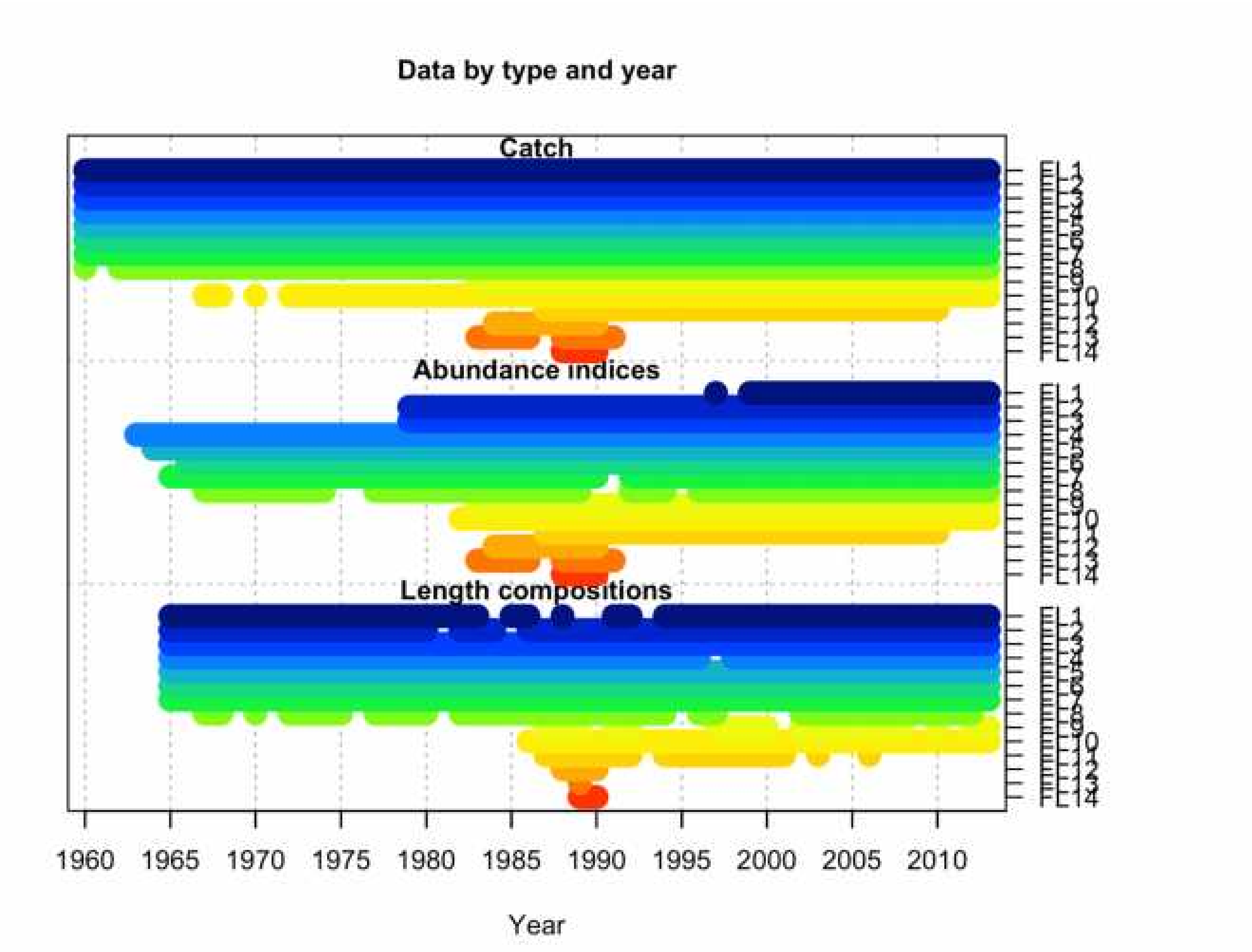


Figure 1. Presence of catch, standardized CPUE, and length composition data by year and fishery.

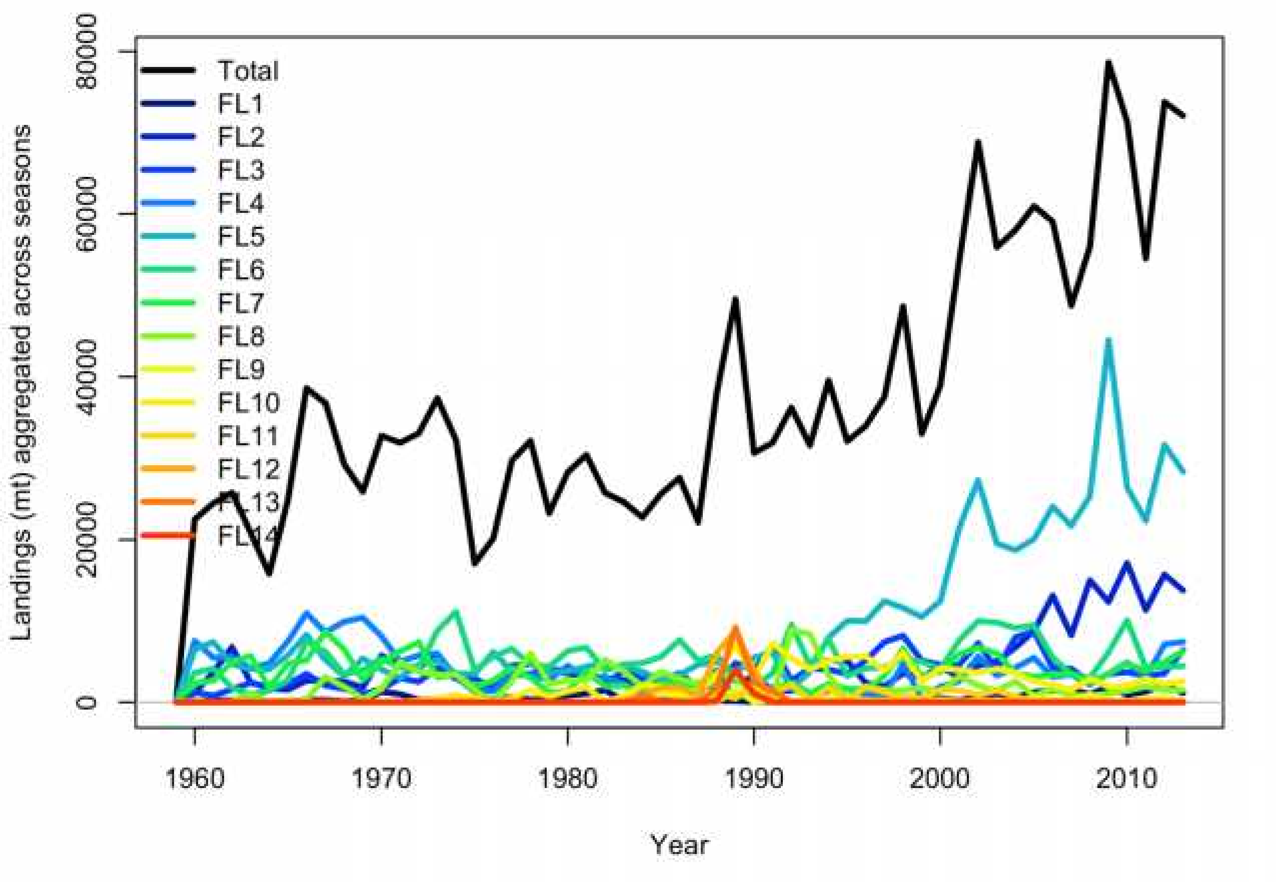


Figure 2. Total annual landings (mt) by fishery from the base case model.

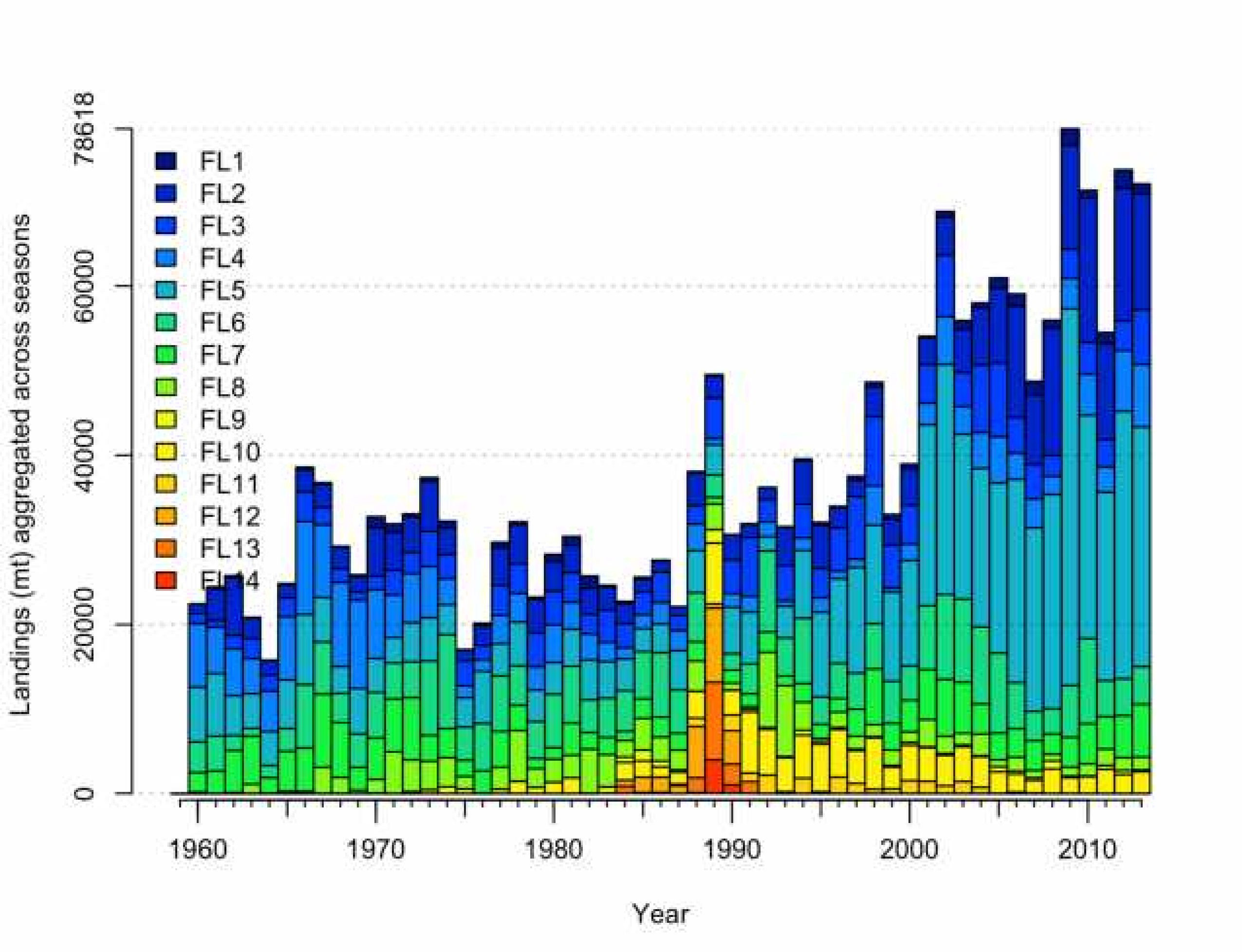


Figure 3. Total annual landings (mt) aggregated across seasons stacked from the base case model.

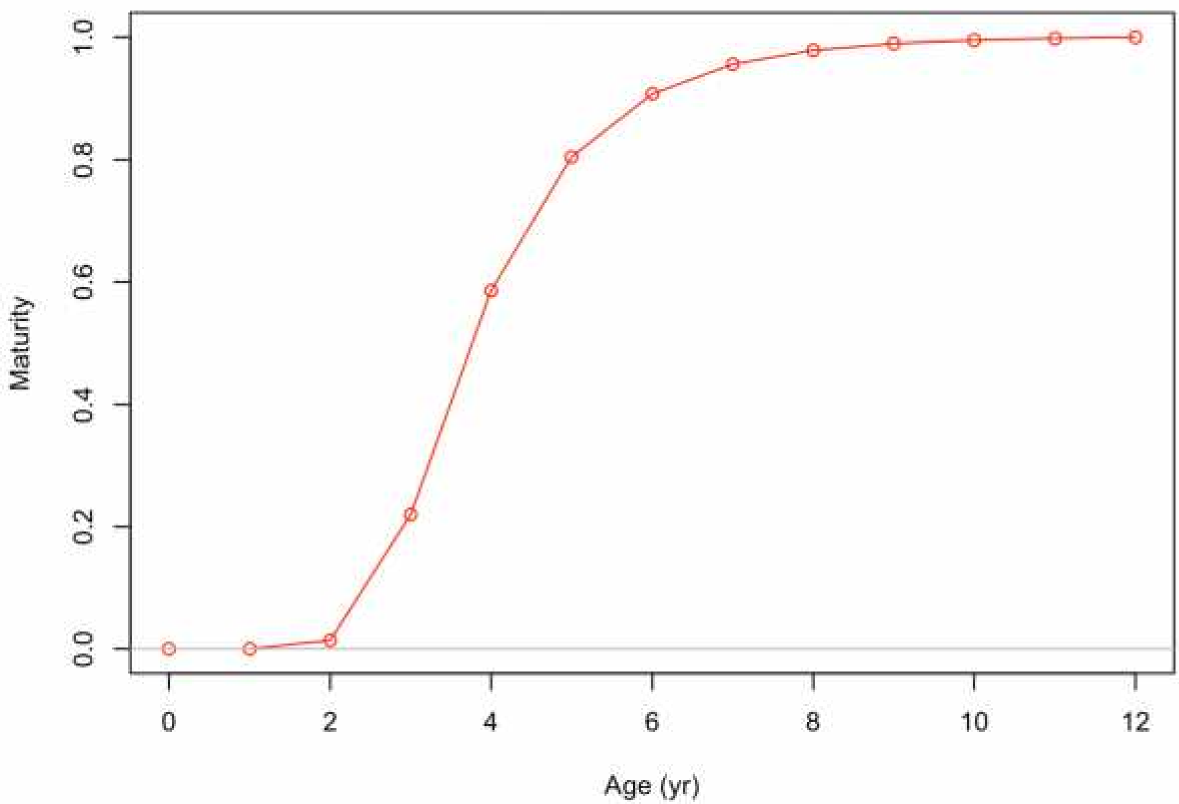


Figure 4. Maturity-at-age as assumed in the base case model.

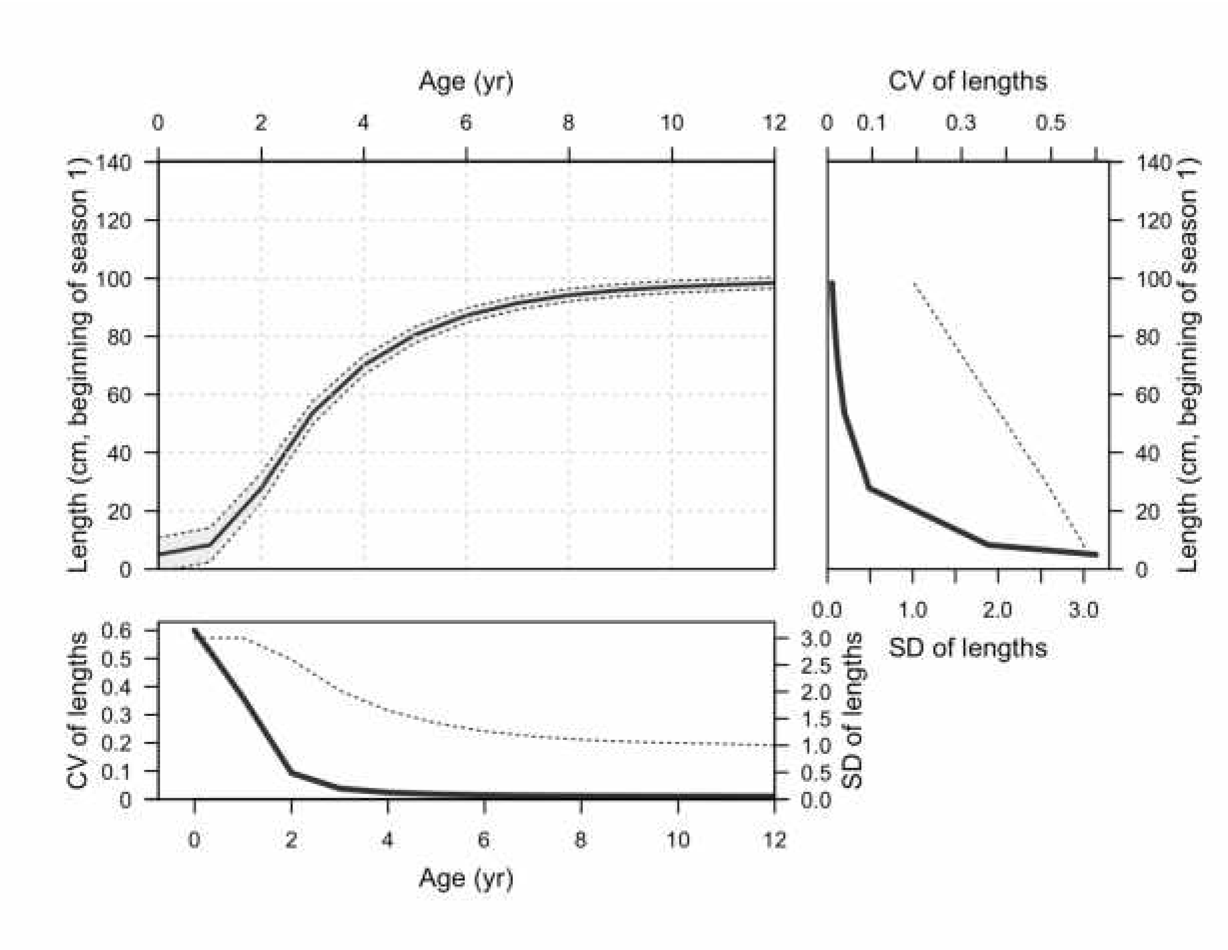


Figure 5. Length-at-age (top-left panel) with CV (thick line) and SD (thin line) of length at age shown in top-right and lower-left panels assumed in the based case.

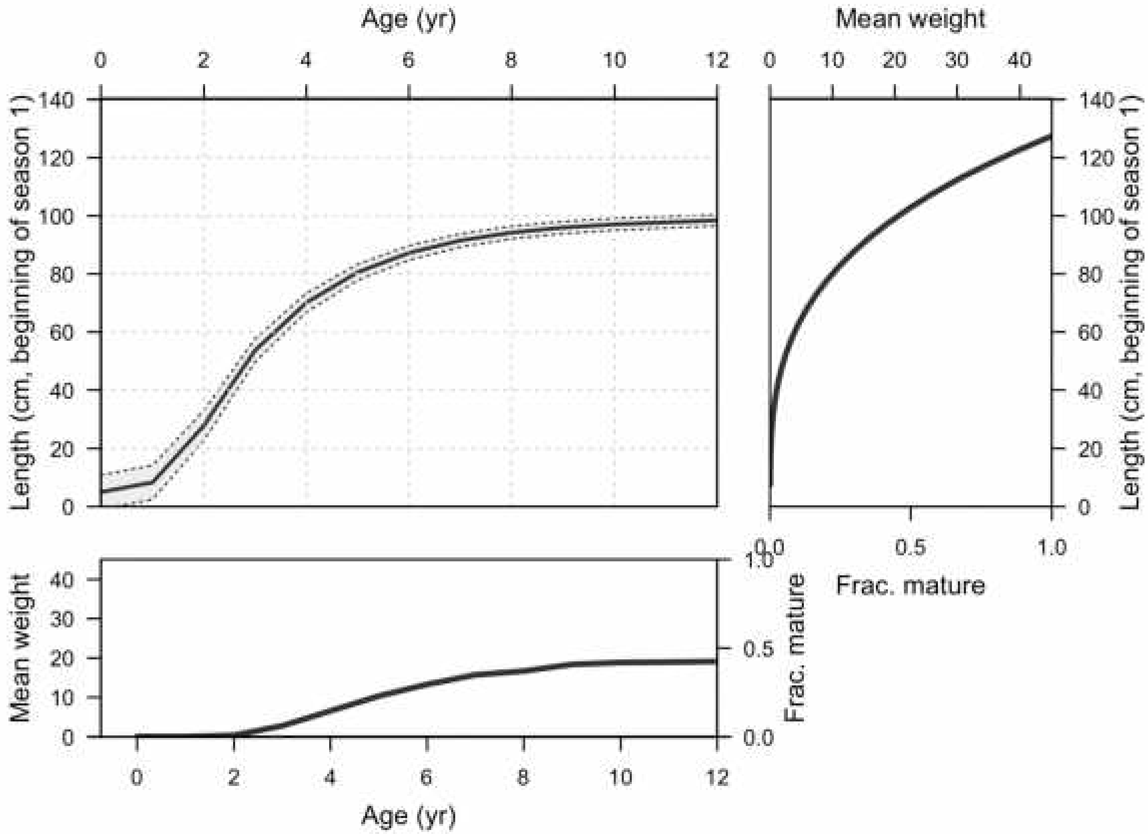


Figure 6. Length-at-age (top-left panel) with weight (thick line) and maturity (thin line) shown in top-right and lower-left panels.

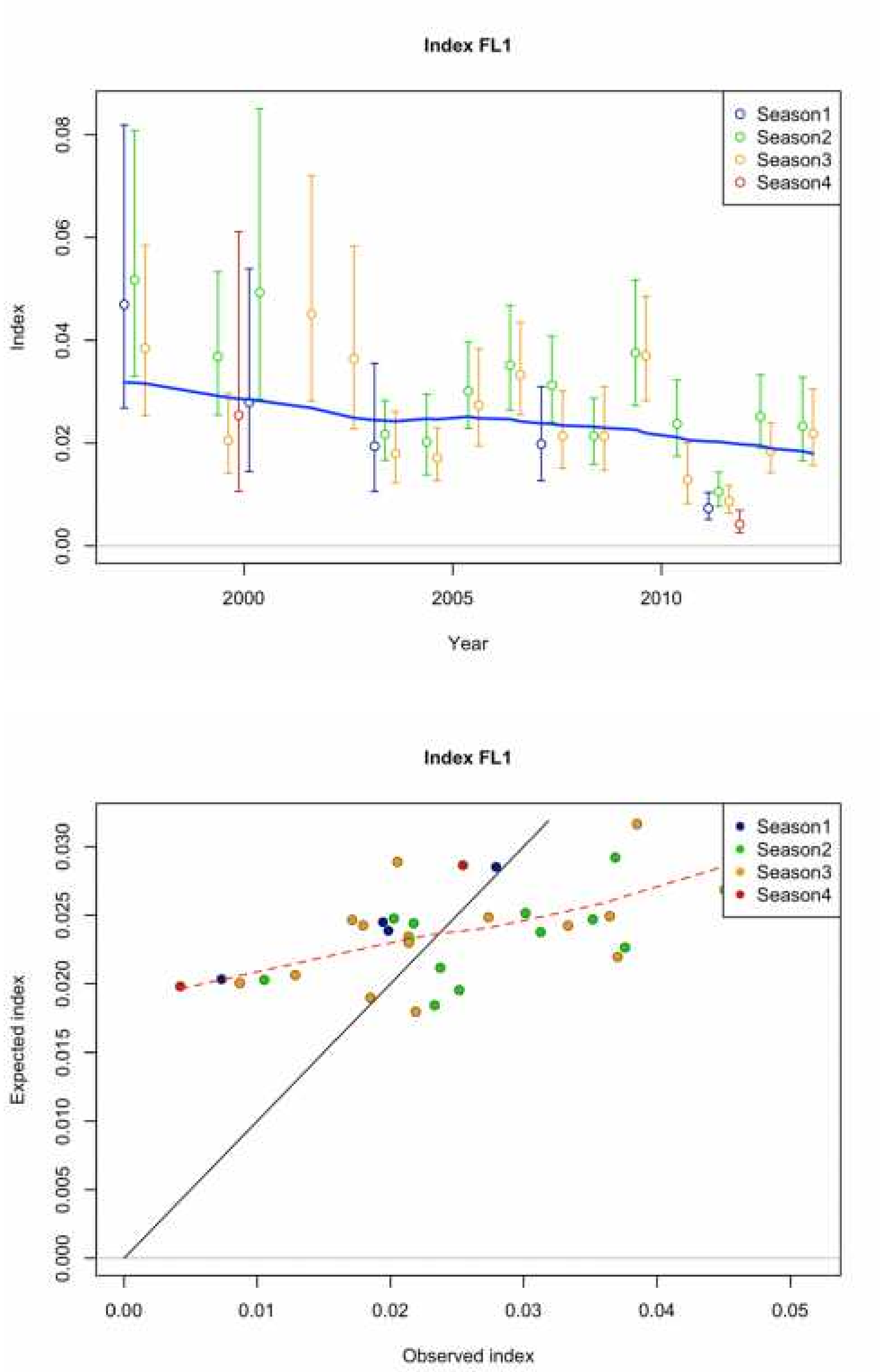


Figure 7. Fit to CPUE index data for fishery 1.

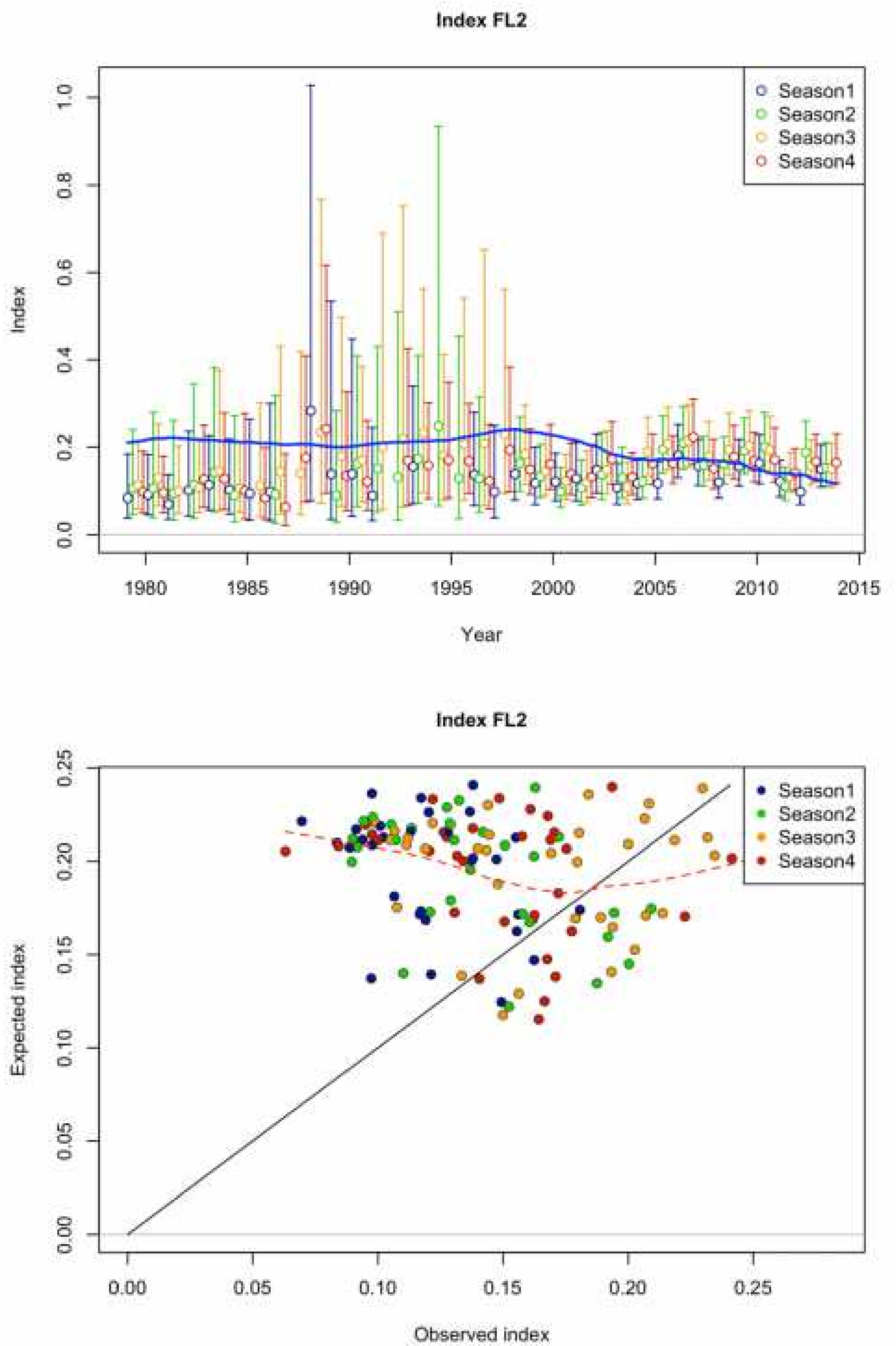
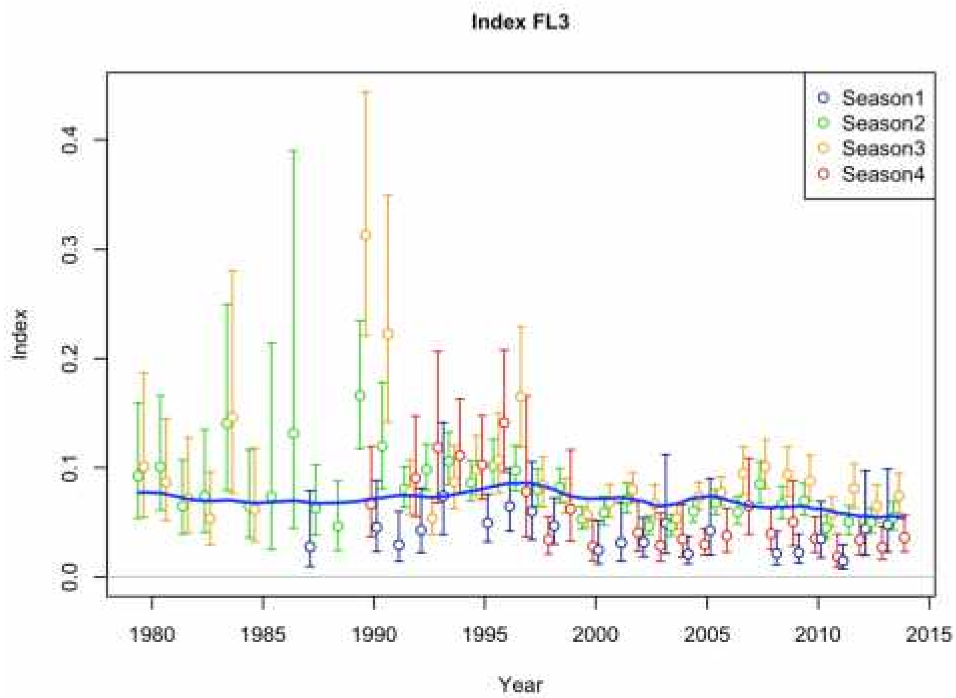


Figure 8. Fit to CPUE index data for fishery 2.



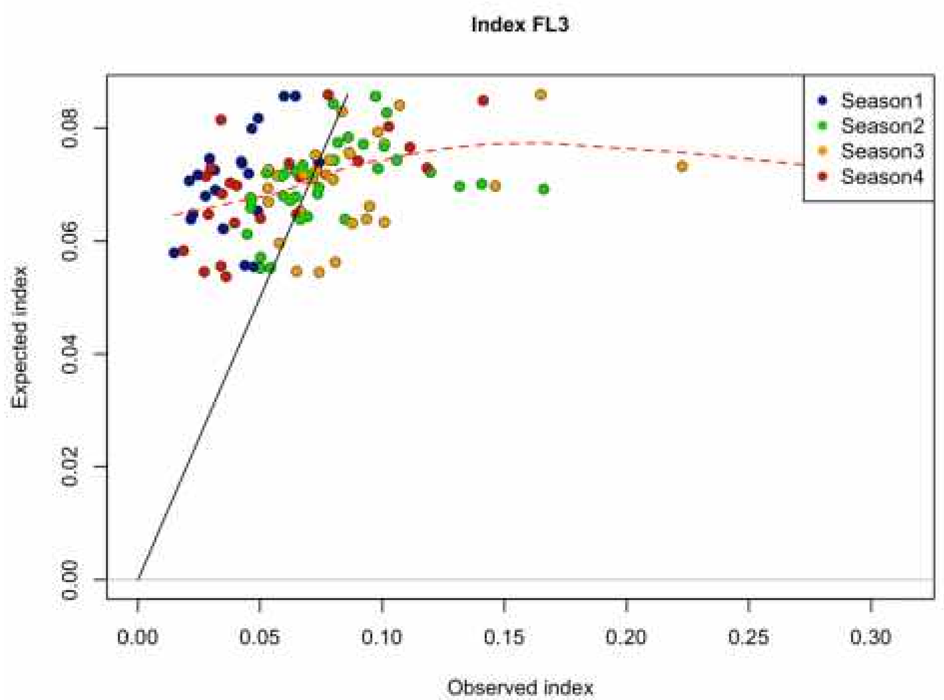


Figure 9. Fit to CPUE index data for fishery 3.

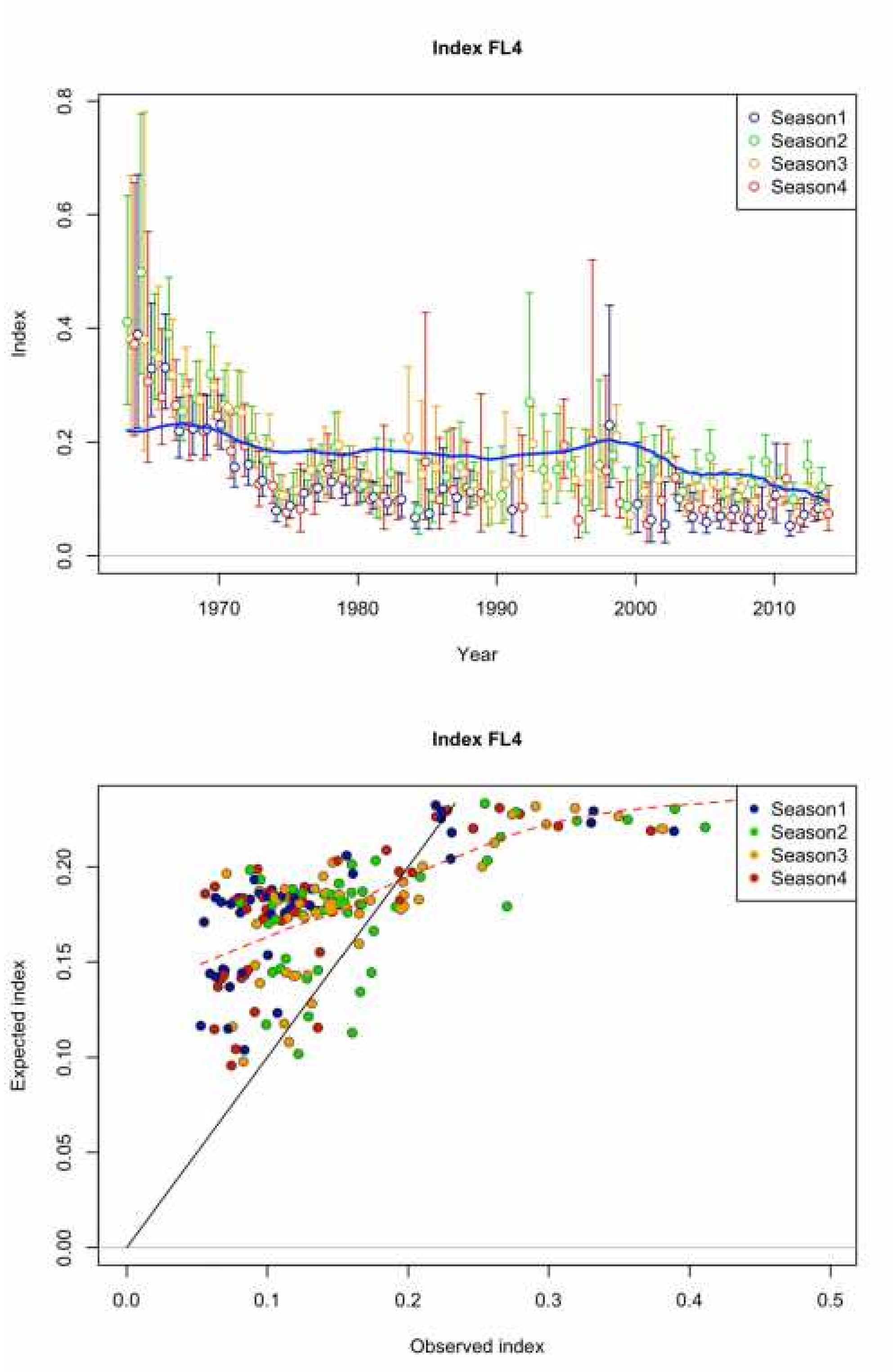


Figure 10. Fit to CPUE index data for fishery 4.

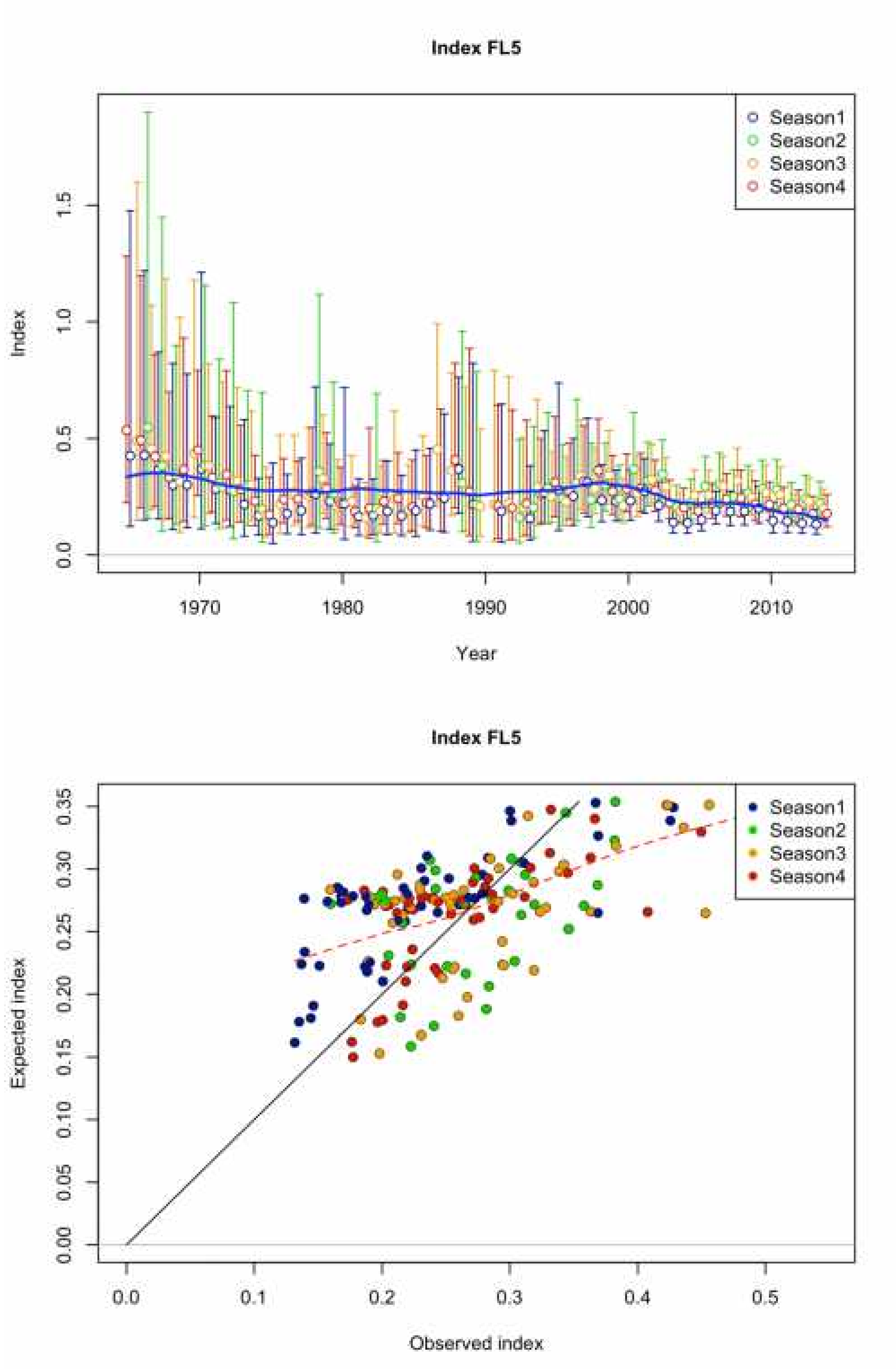


Figure 11. Fit to CPUE index data for fishery 5.

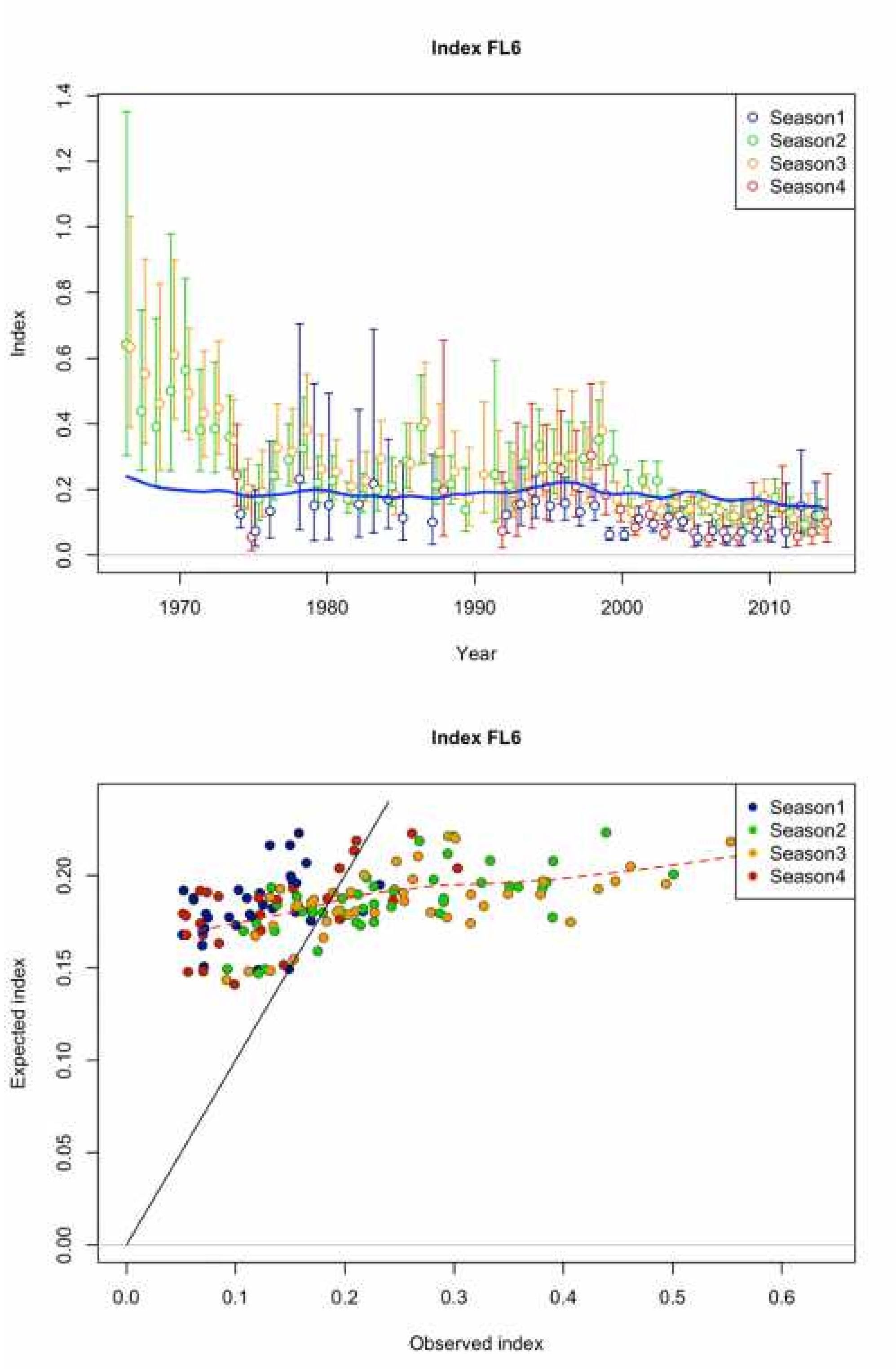


Figure 12. Fit to CPUE index data for fishery 6.

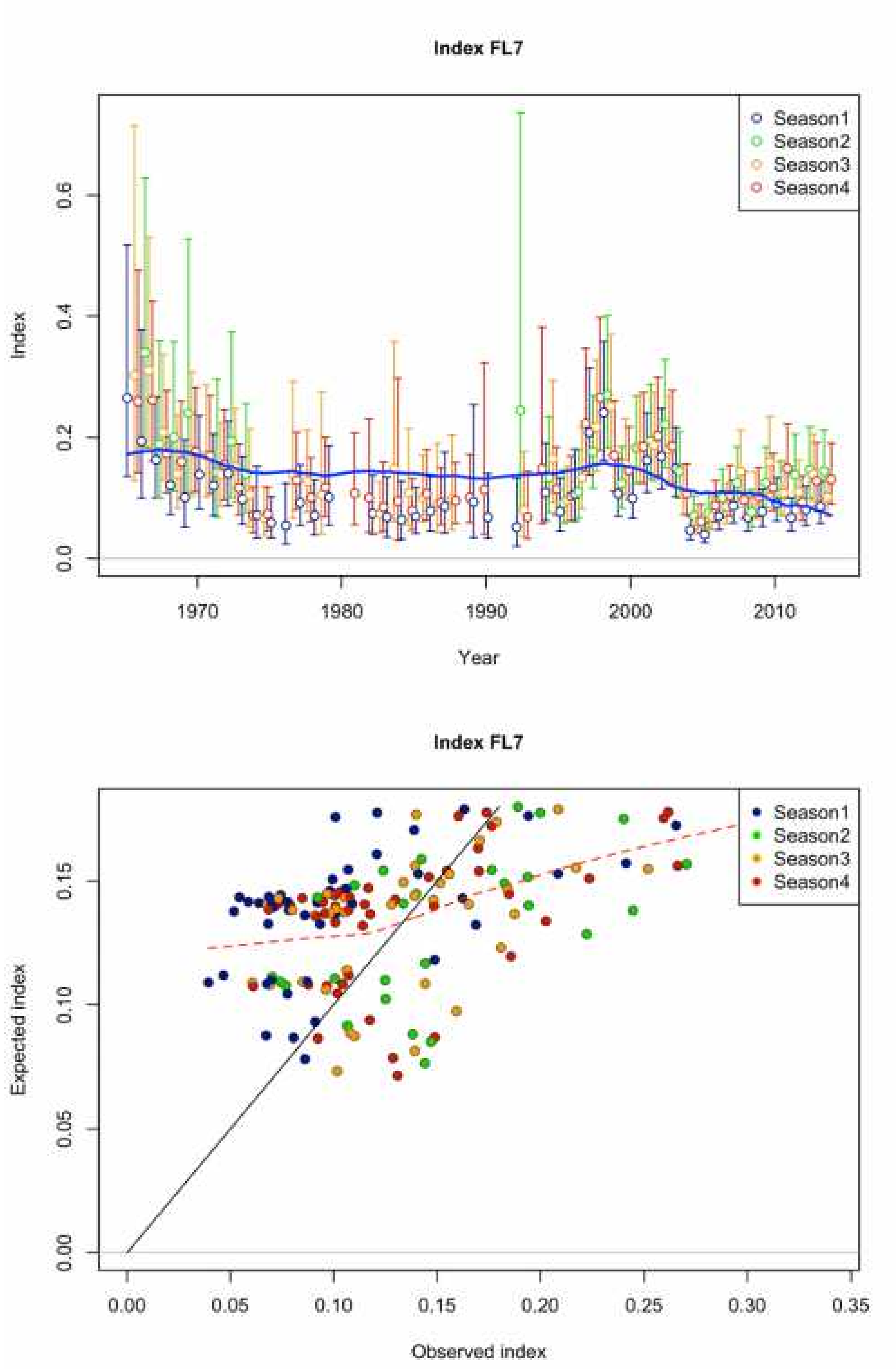
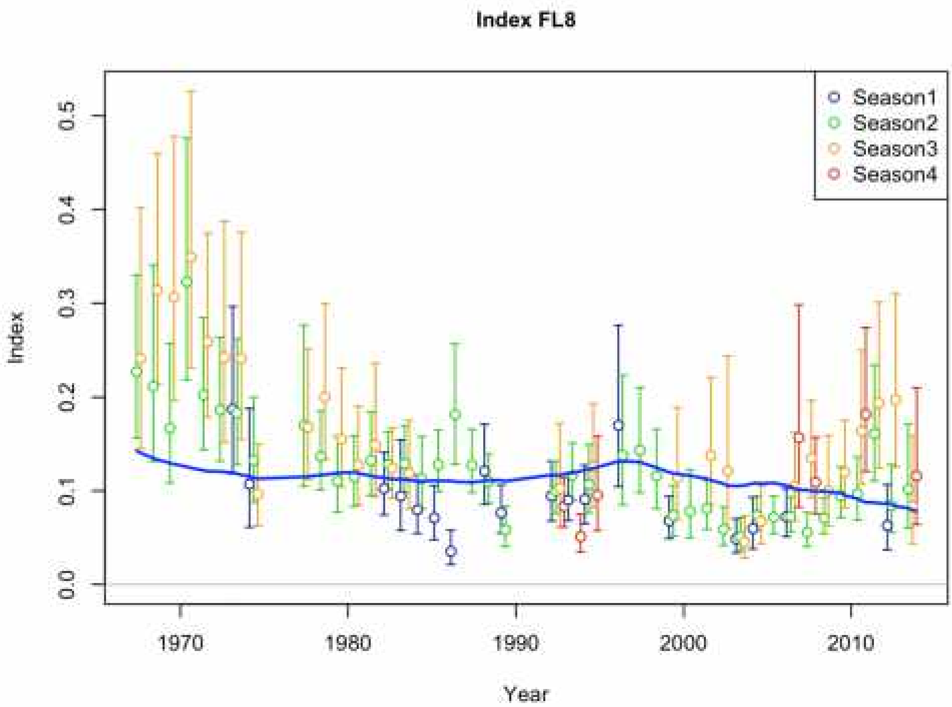


Figure 13. Fit to CPUE index data for fishery 7.



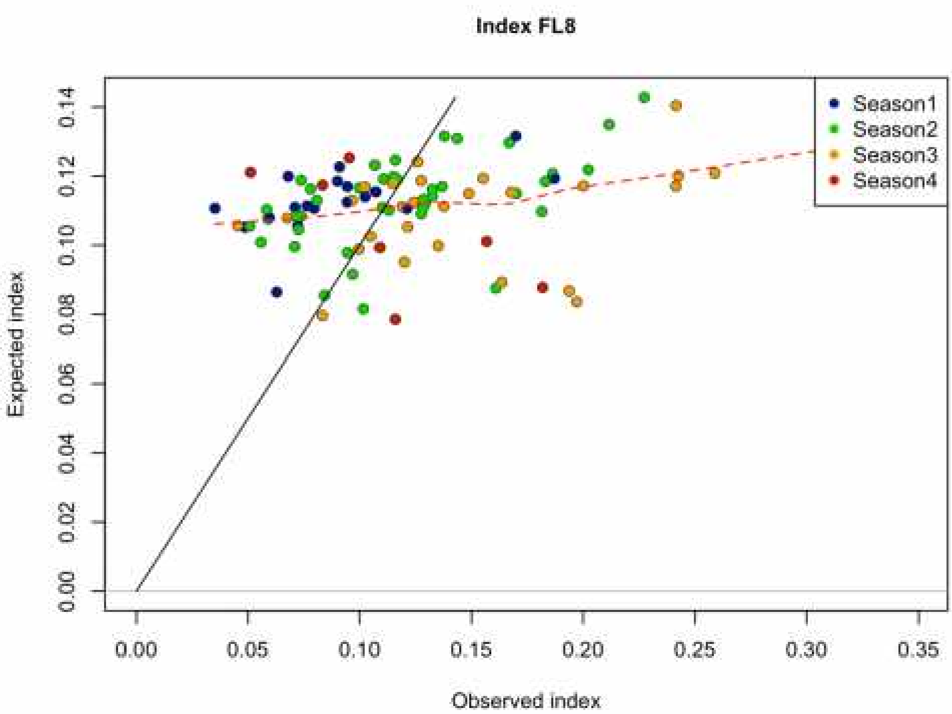


Figure 14. Fit to CPUE index data for fishery 8.

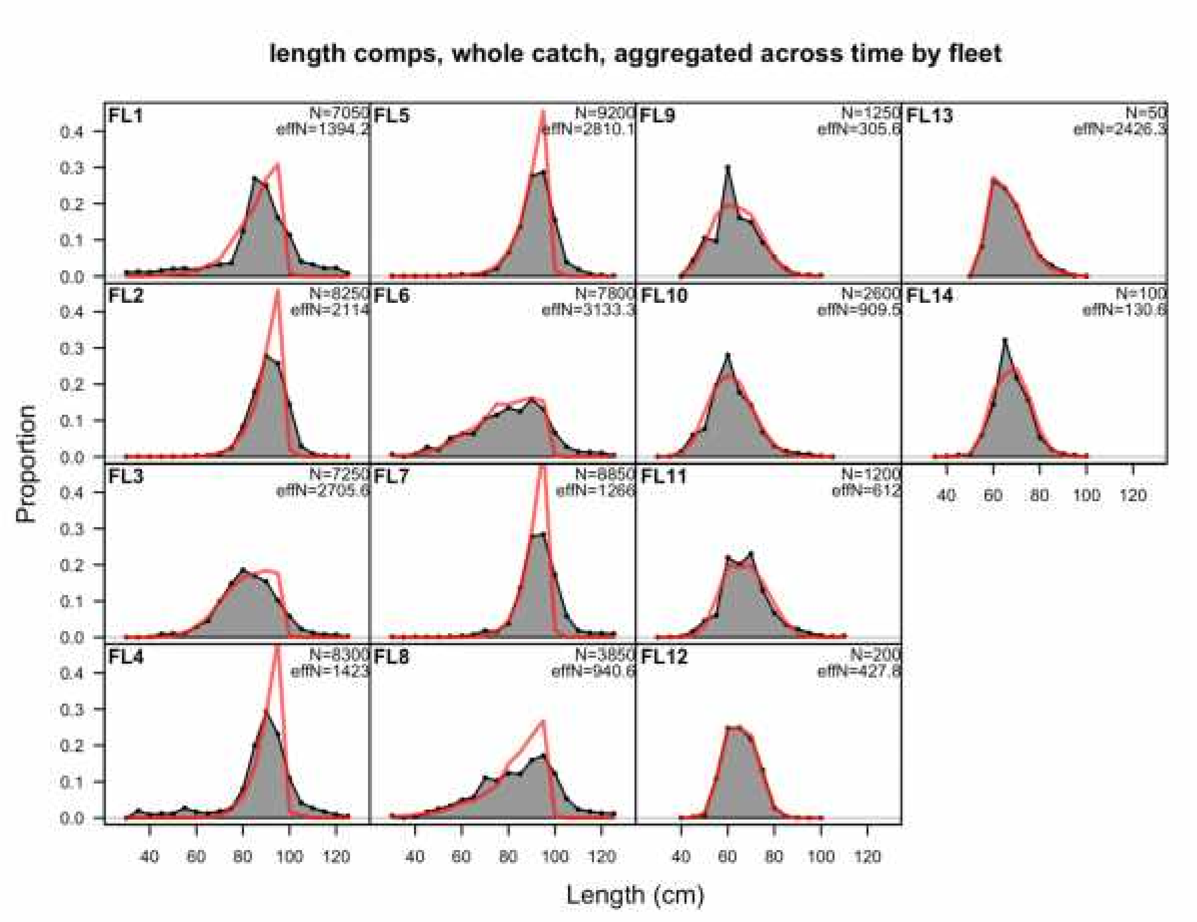


Figure 15. Composite (all time periods combined) observed (red line) and predicted (gray polygon) catch at length for all fisheries for the base case.

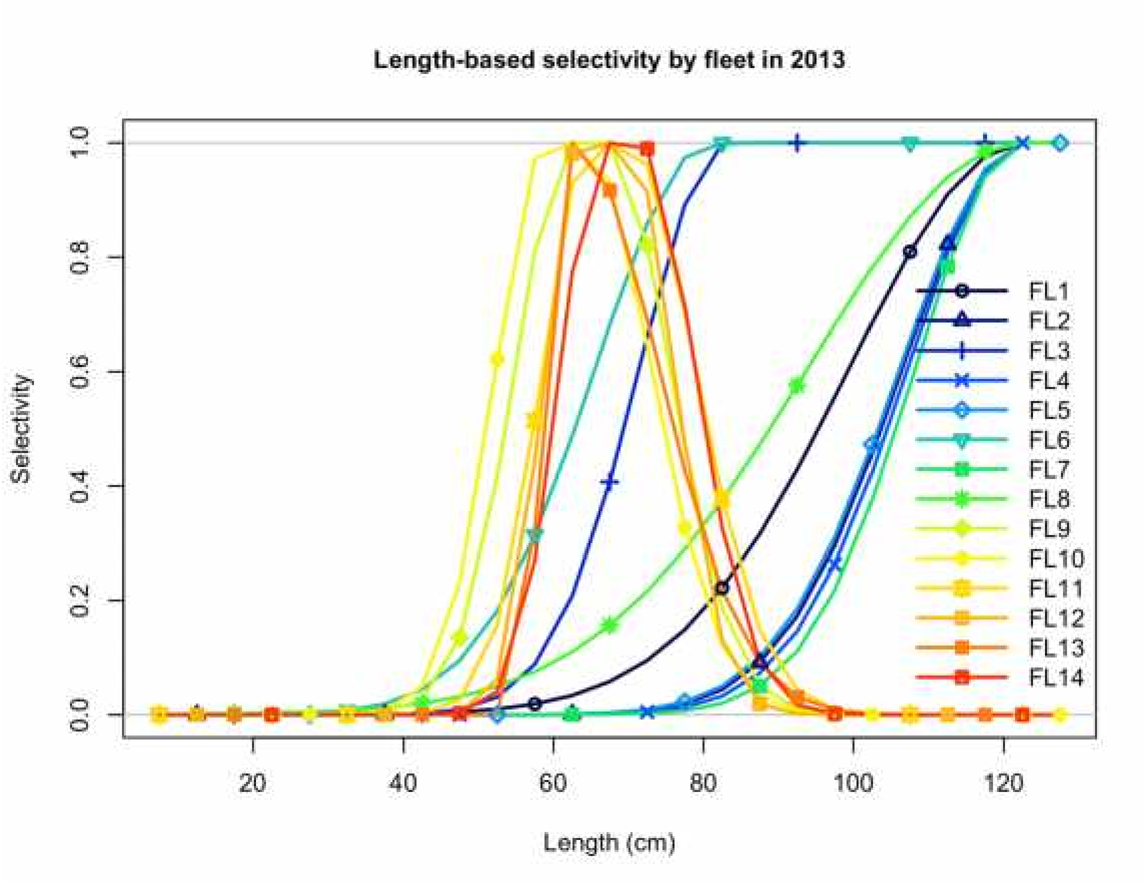


Figure 16. Estimated length-specific selectivity by fishery.

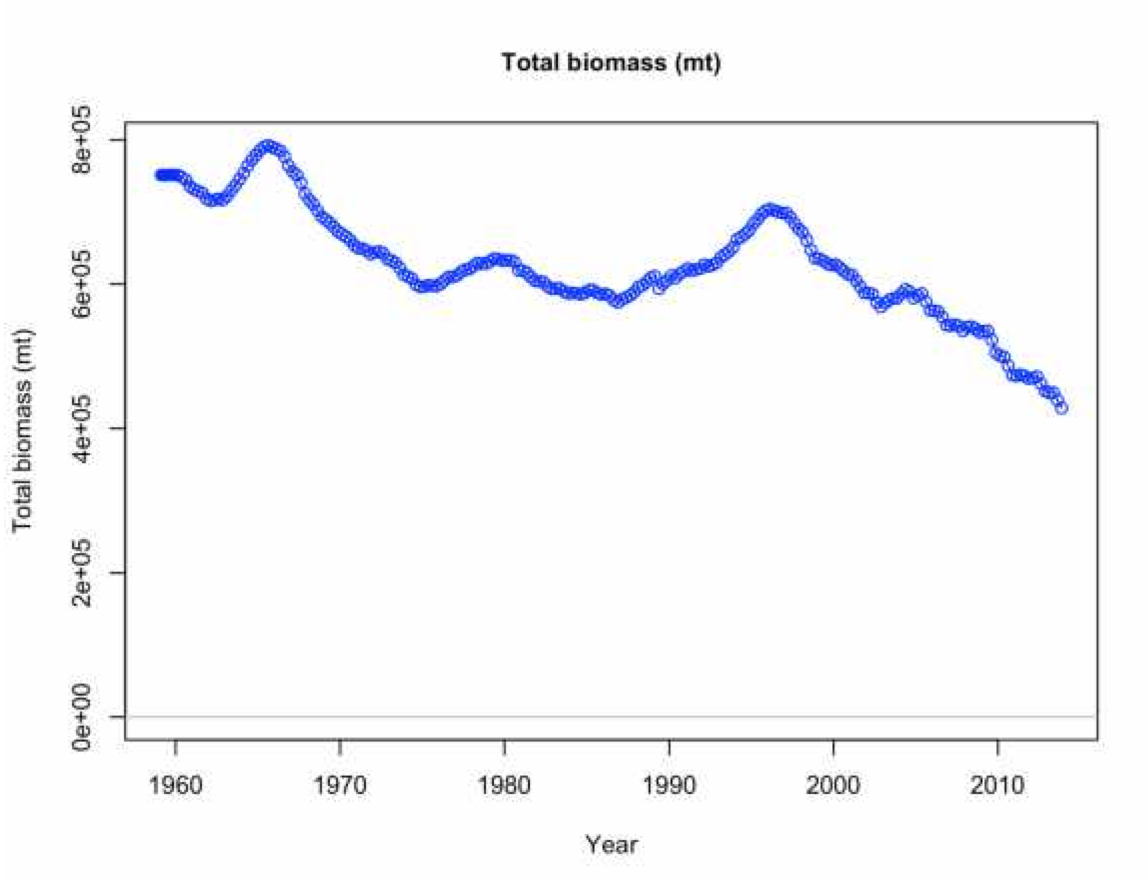


Figure 17. Estimated time series of total biomass for the base case.

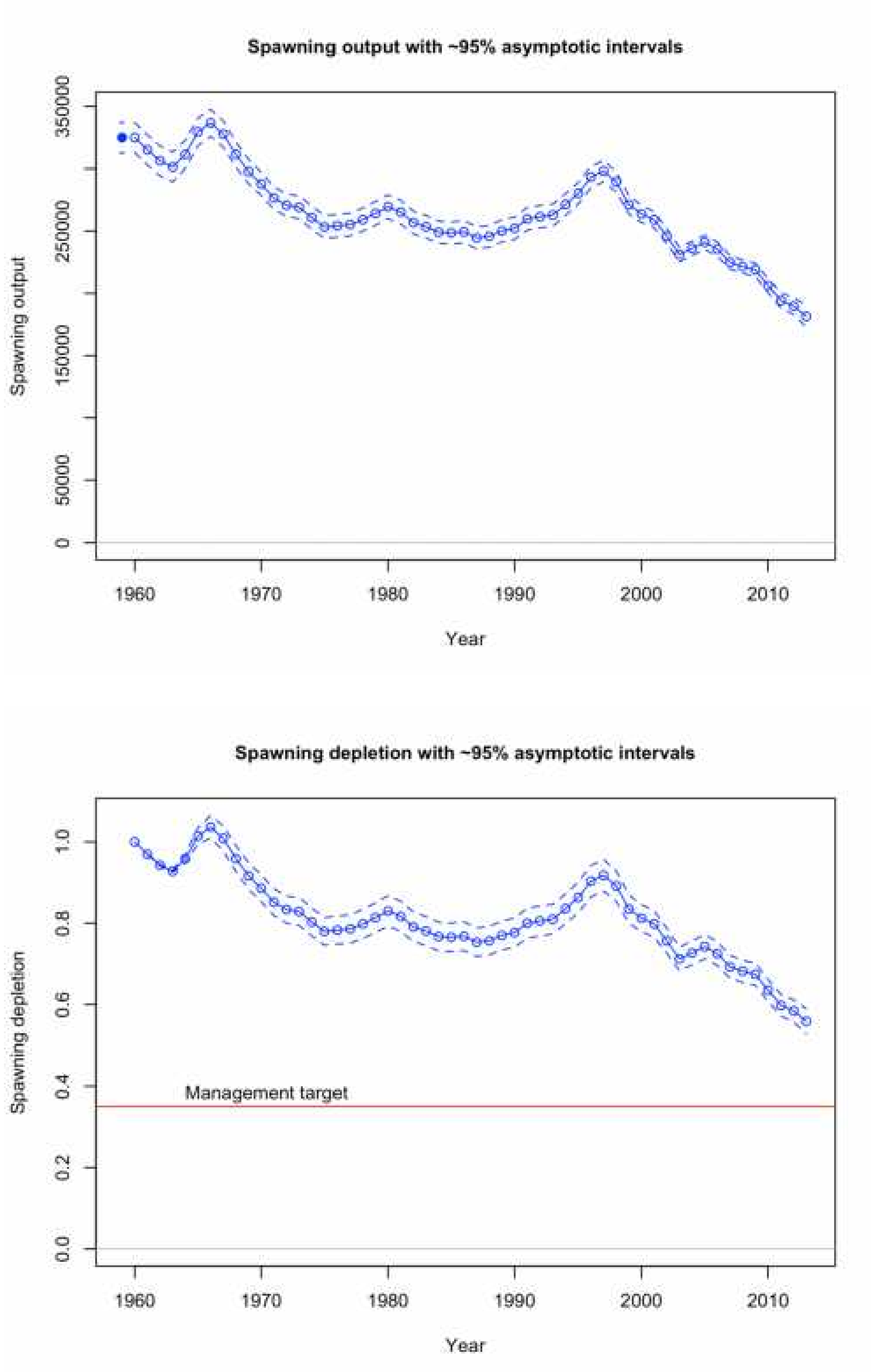


Figure 18. Estimated spawning output and spawning depletion with 95% asymptotic intervals.

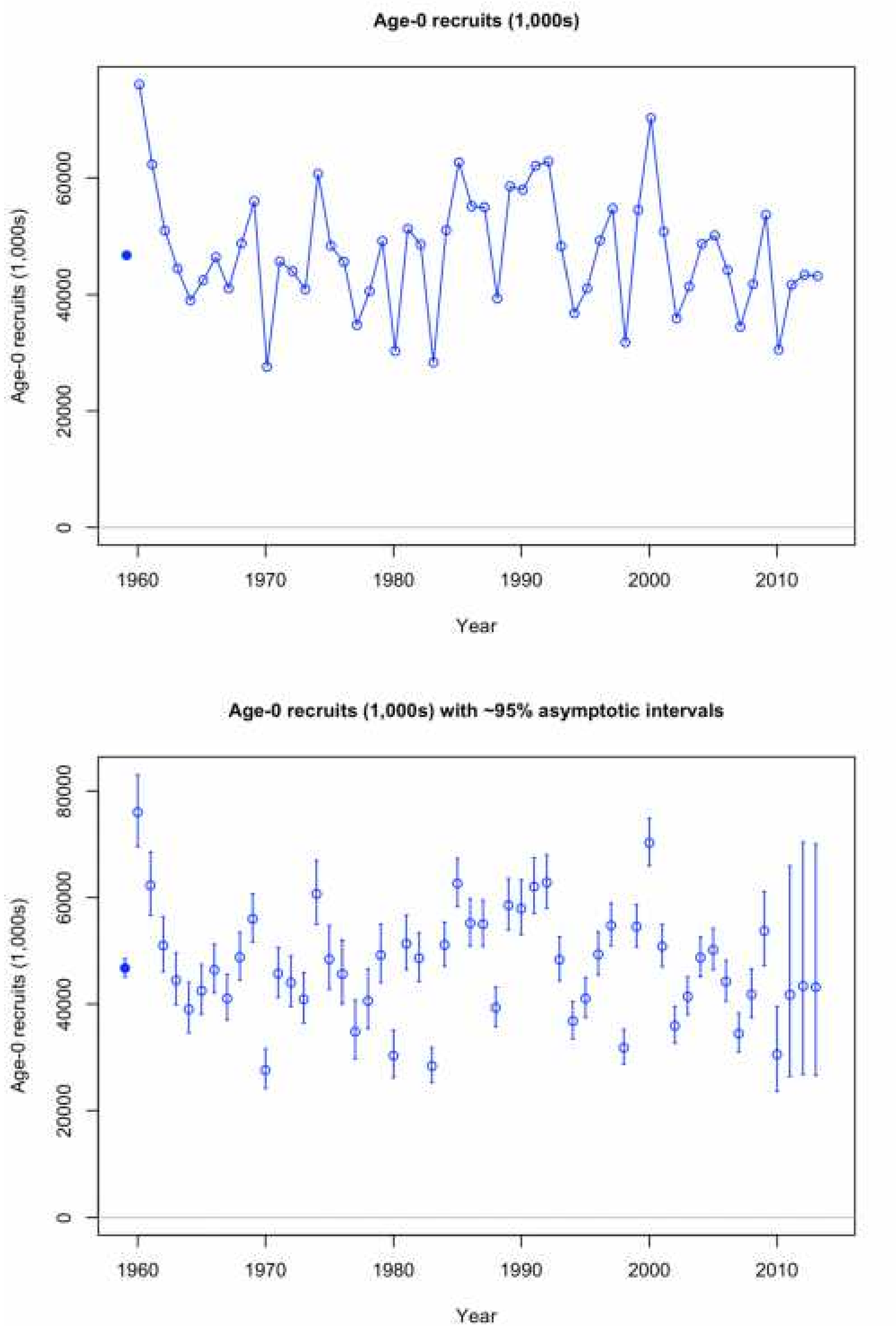
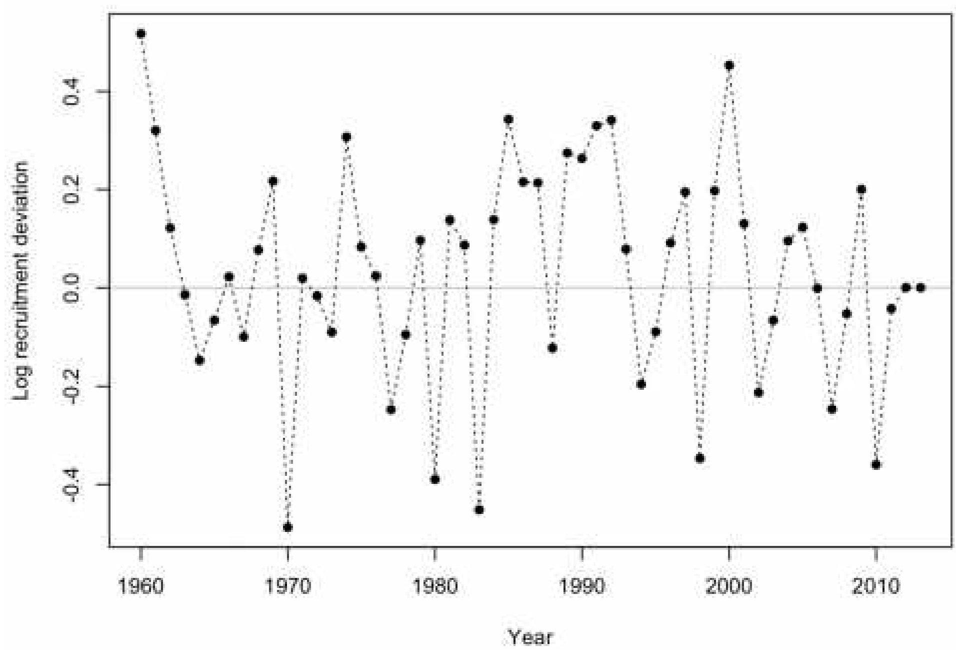


Figure 19. Estimated annual recruitment and recruitment with 95% asymptotic intervals.



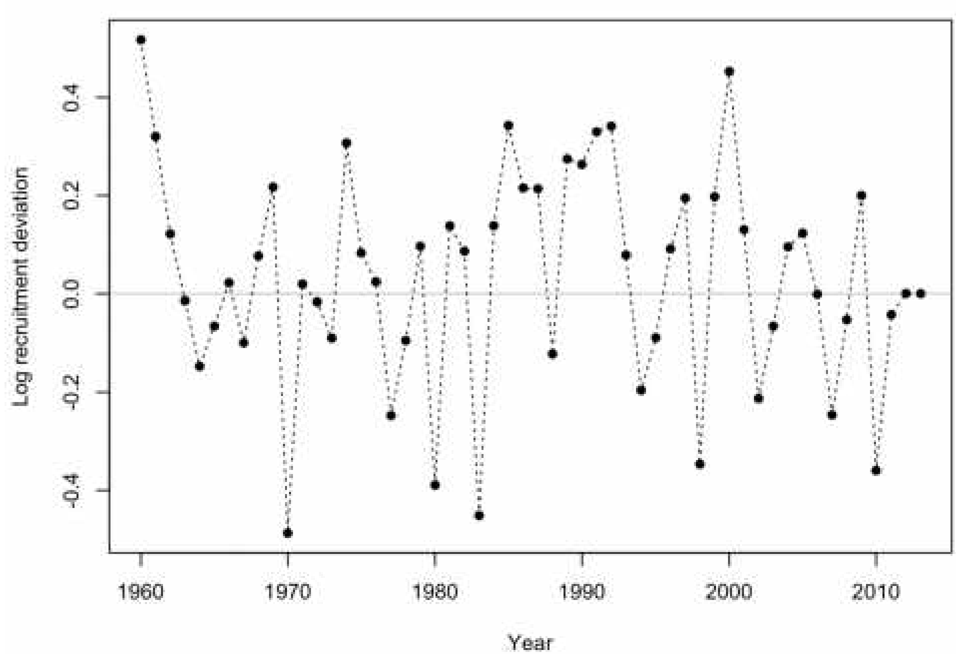
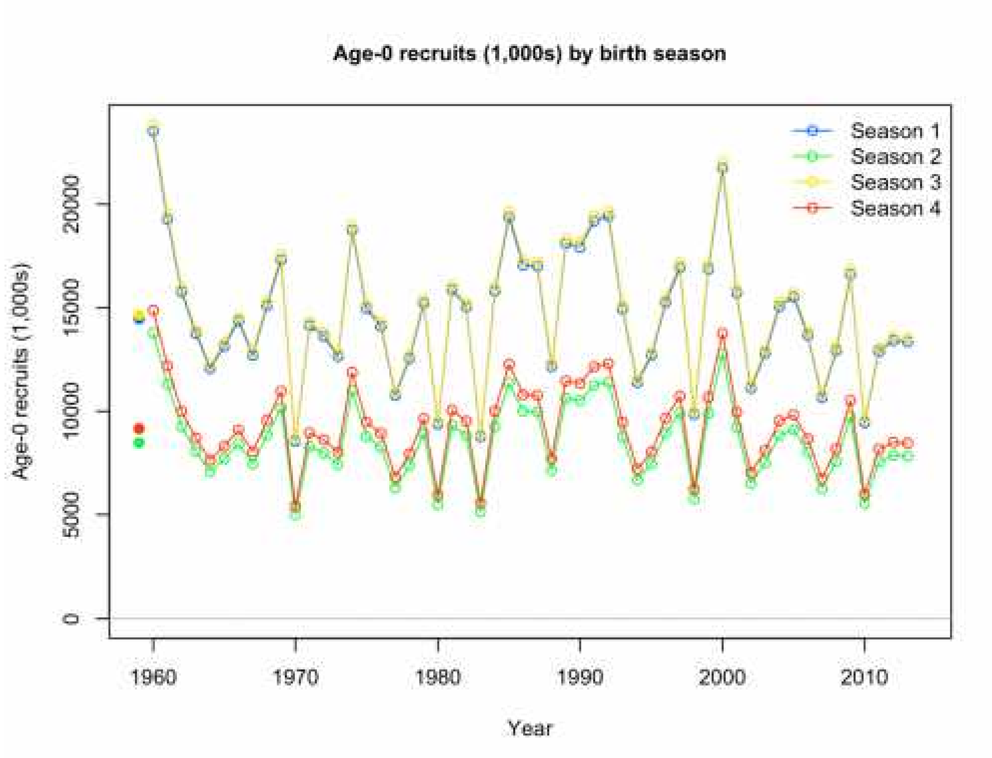


Figure 20. Estimated log recruitment deviation and deviation with 95% asymptotic intervals.



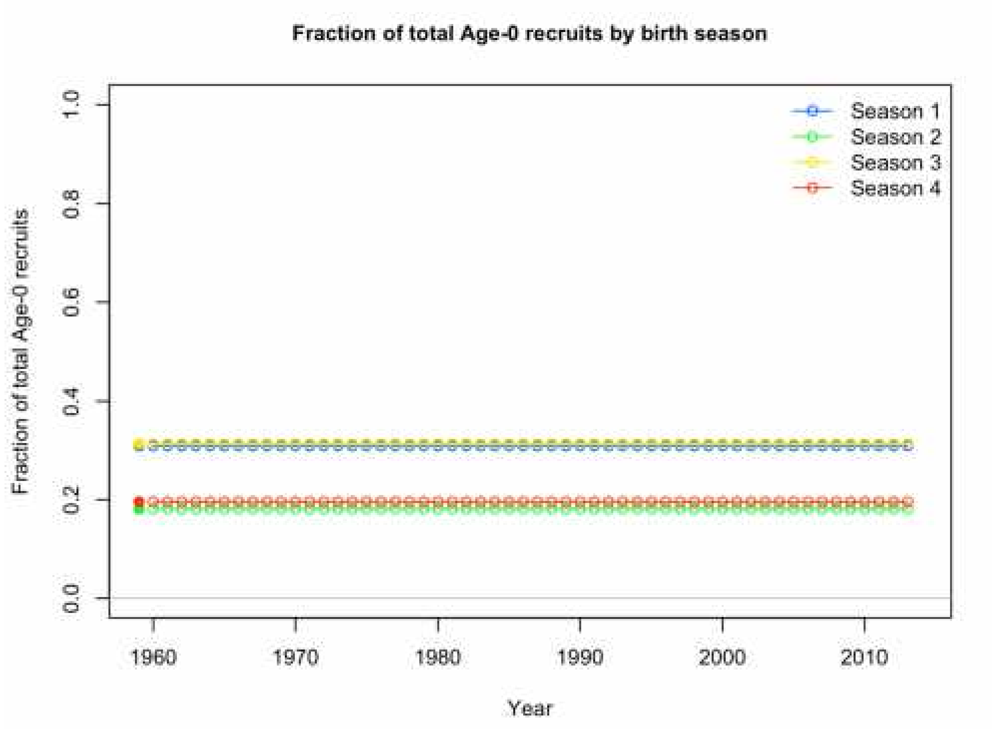


Figure 21. Estimated recruitment and fraction of total recruitment by birth season.

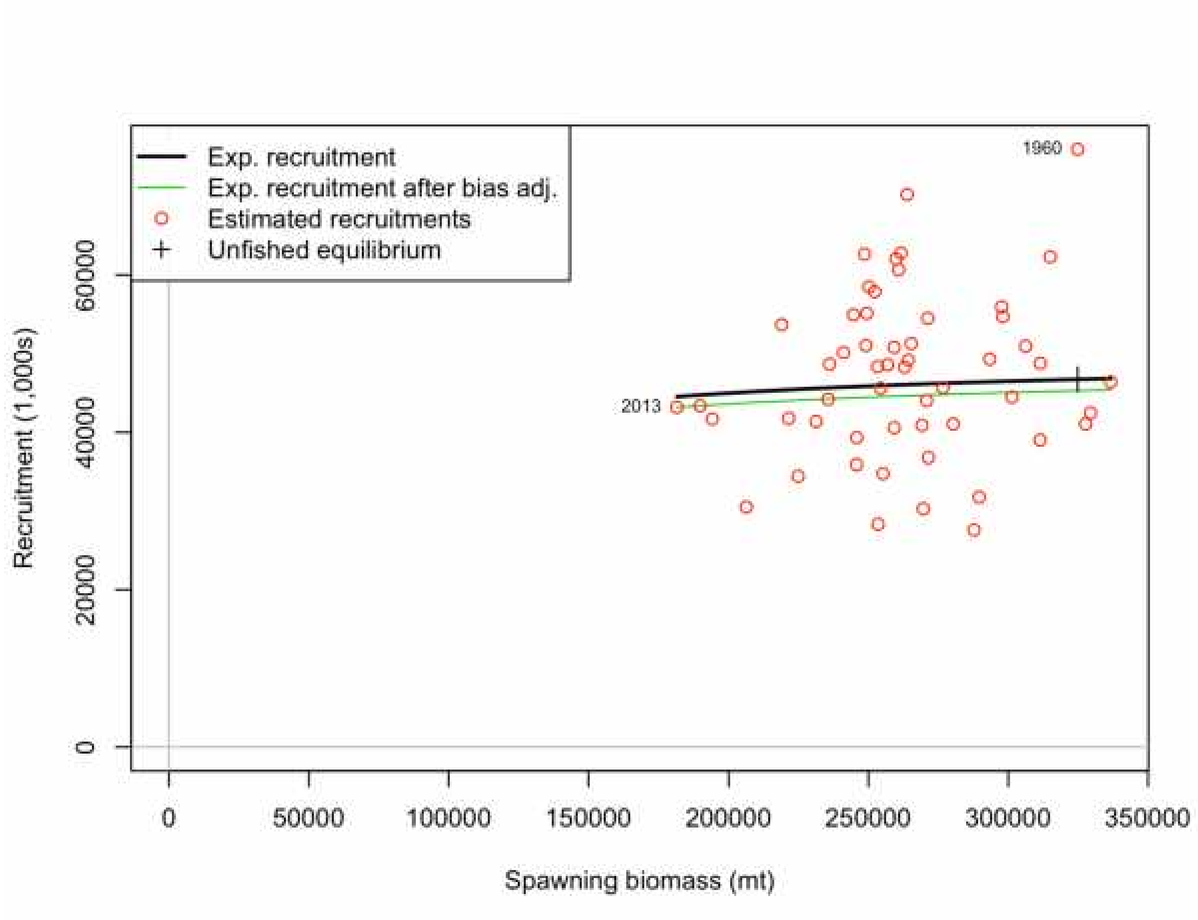


Figure 22. Estimated Spawner-recruit curve with labels on first, last, and years with (log) deviations > 0.5.

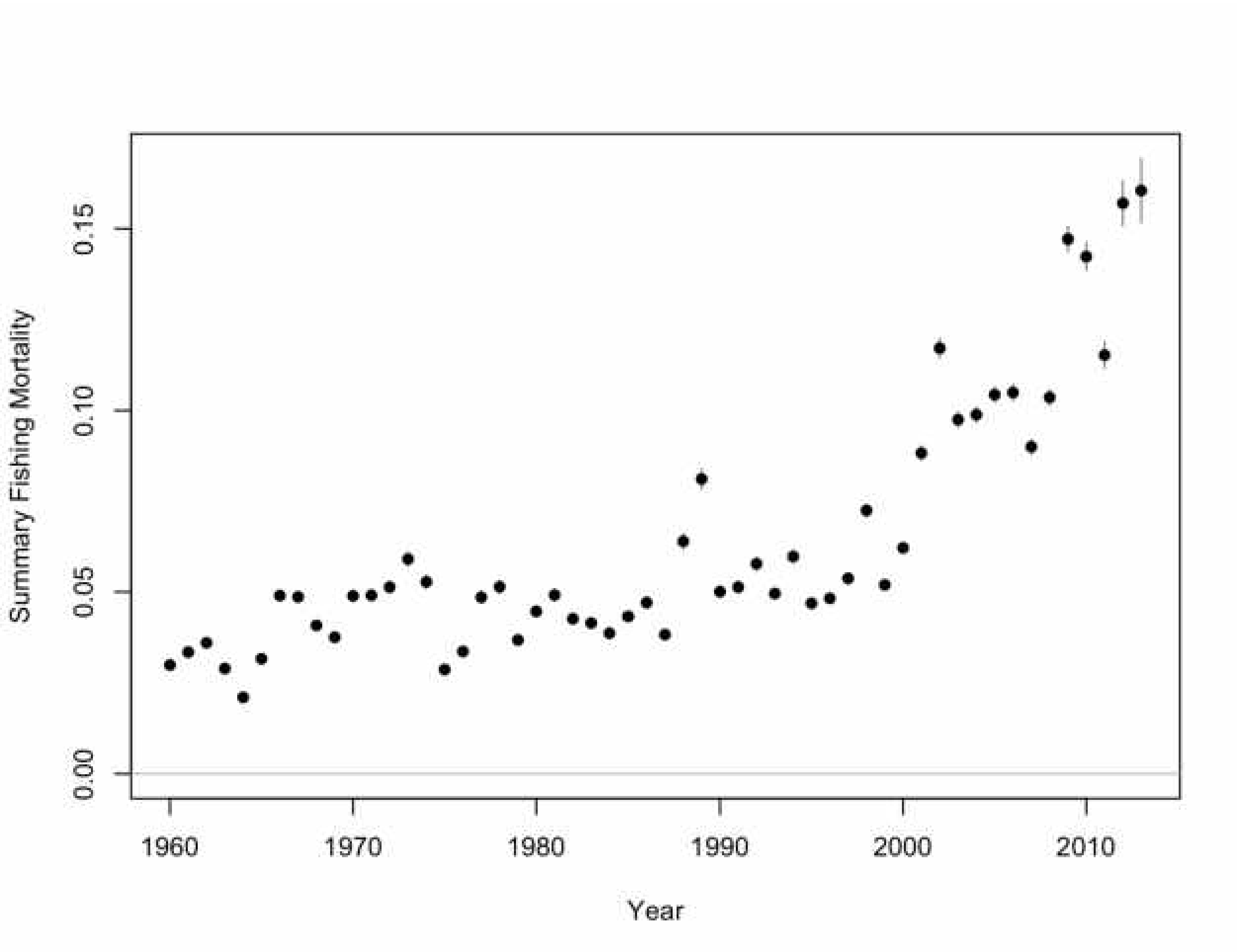


Figure 23. Estimated annual fishing mortality with 95% asymptotic intervals.

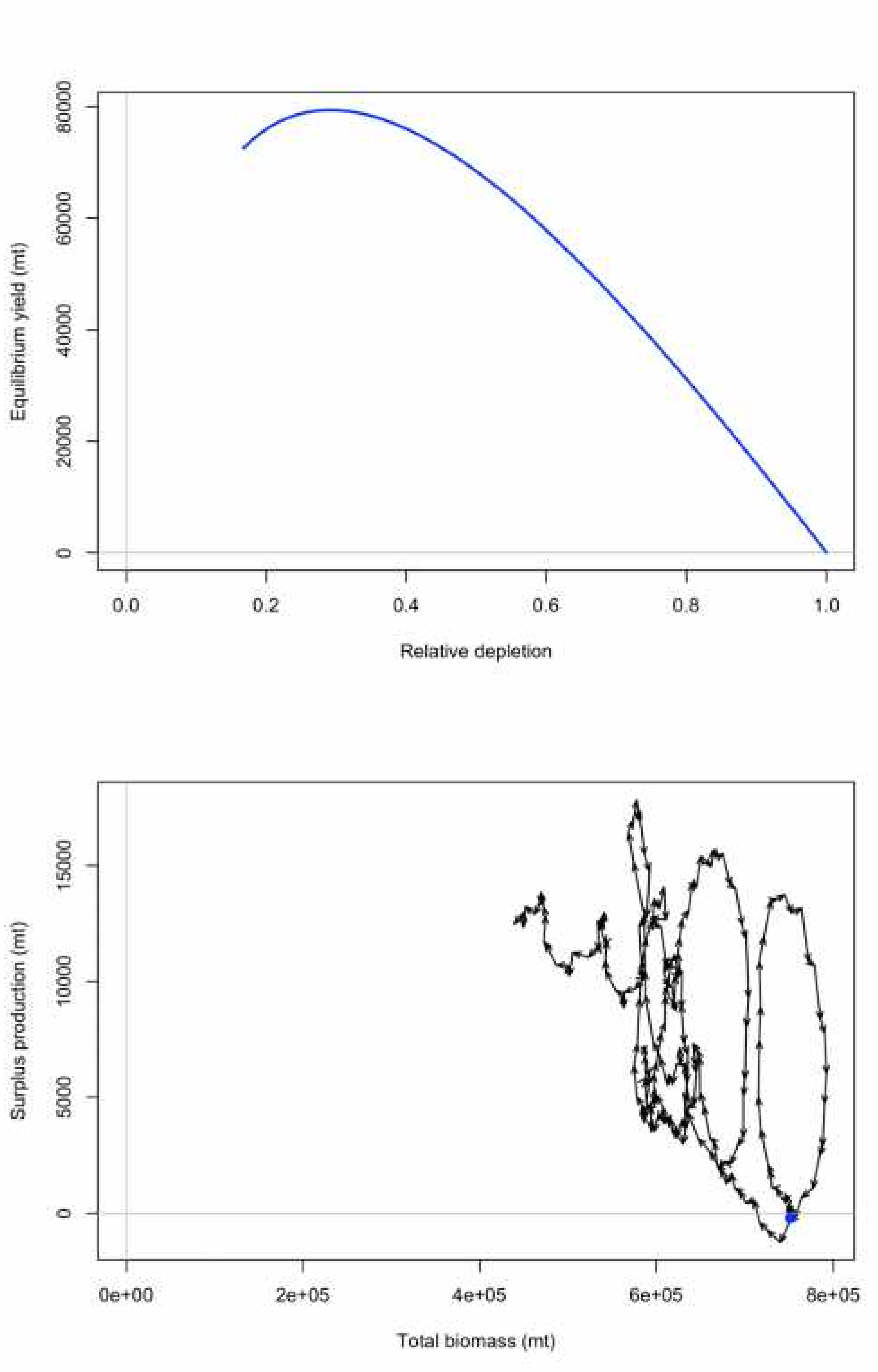


Figure 24. Estimated yield curve and surplus production plot.

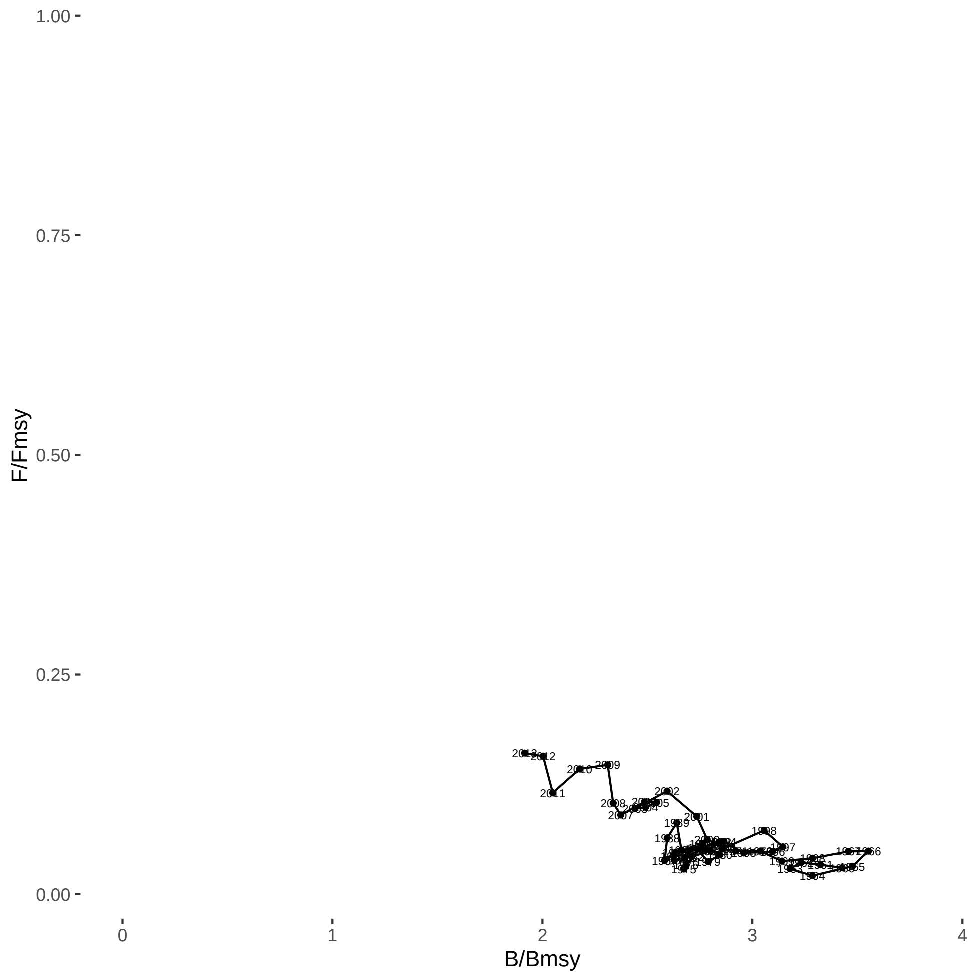


Figure 25. Kobe plot for the base case model.