SCTB15 Working Paper

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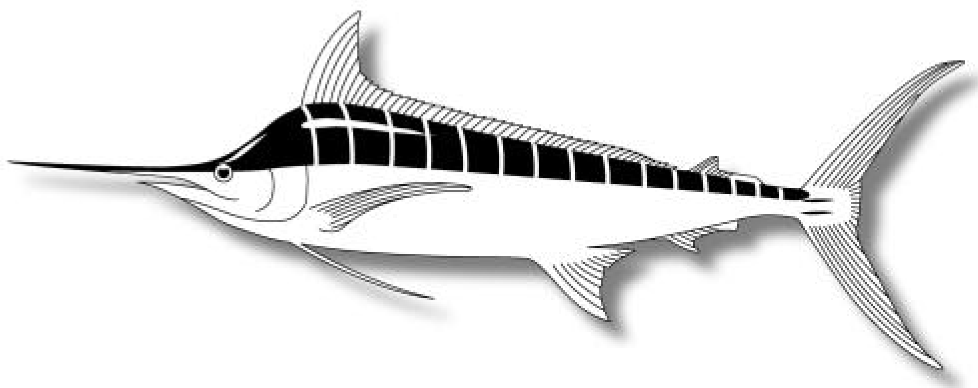
Stock assessment of swordfish in the North Pacific using MULTIFAN-CL



Pierre Kleiber[1] and Kotaro Yokawa[2]

[1]National National Marine Fisheries Service (NMFS), Honolulu Laboratory, Hawaii

[2] National Research Institute of Far Seas Fisheries, Shimizu, Japan

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Stock Assessment of Swordfish in the North Pacific using MULTIFAN-CL[1, 2]

Pierre Kleiber
Honolulu Laboratory, SWFSC
National Marine Fisheries Service, NOAA
Honolulu, Hawaii, U.S.A.

and

Kotaro Yokawa
National Research Institute of Far Seas Fisheries
Shimizu, Japan

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North Pacific Swordfish Stock Assessment using MULTIFAN-CL

Pierre Kleiber and Kotaro Yokawa

Introduction

Recent analyses of the status of the swordfish in the North Pacific based on production-type models have shown that the population has been only lightly affected by past levels of fishing effort (Anon, 1999). However, the findings were preliminary and the uncertainty levels great. Experience has shown that assessment models can be deceiving (e.g. Walters and MaGuire, 1996). Precaution dictates that confirmation of conclusions from one analytical approach should be sought by trying alternative approaches. Therefore, a new assessment based on MULTIFAN-CL was undertaken as a collaborative effort between the National Research Institute for Far Seas Fisheries and the Honolulu Laboratory, NOAA Fisheries. This paper is a progress report from early stages of that collaboration for presentation to the 3rd meeting of the Interim Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC).

Data

Japanese longline effort and swordfish catch data from 1952 through 2000 were aggregated into quarterly time periods and into four large regions in the North Pacific (Fig. 1). The regions were divided longitudinally at 160°E and latitudinally at 30°N. Data south of 10°N were excluded. Size sample data from Japanese longline research and training vessels were aggregated in the same way and into 5 cm eye to fork length bins. Hawai'i longline effort and swordfish catch from 1990 through 2000 were treated in the same way along with along with size sample data from on-board scientific observers. Data from other fleets that catch swordfish in the North Pacific have not as yet been obtained and processed for input into MULTIFAN-CL. These include other longline fleets from Taiwan, Korean and elsewhere as well as other gears such as drift net and harpoon.

Assessment Method

MULTIFAN-CL is a length-based, age-structured, spatially heterogeneous, stock assessment model that makes use of catch, effort, and size sample data from multiple fleets. It estimates parameters related to recruitment, growth, catchability, selectivity, natural mortality, and movement. From these basic parameters it predicts historical abundance by time, age class, and area. It can also predict theoretical abundances and yields under various hypothetical fishing regimes. Growth is assumed to follow a von Bertalanffy curve with a normal distribution of sizes about the curve. Mean length for a number of early ages can be estimated independently of the von Bertalanffy curve. The standard deviation of that distribution is assumed to change linearly with age. A detailed description of MULTIFAN-CL, its population dynamics model, and parameter estimation techniques are given by Fournier et al., (1998) and Hampton and Fournier (in press).

Six fleets were considered in the analysis: four Japanese longline fleets in the northwest, northeast, southwest and southeast regions (JLLNW, JLLNE, JLLSW, JLLSE), and two Hawai'i fleets in the northeast and southeast (HLLNE, HLLSE). Parameters of catchability and selectivity were estimated independently for each fleet. Selectivity was constrained to be non-decreasing with age and to be constant for the oldest three age classes. Catchability variation was estimated both seasonally and year to year as a constrained time series.

Fifteen age classes were considered with the oldest being age 15 years and greater. Recruitment was assumed to occur once per year in the third quarter. Swordfish were assumed to mature within the fourth to sixth year following recruitment. Natural mortality was estimated from a broad prior distribution with mean 0.2 $year^{-1}$ and coefficient of variation of 40%. Mean lengths of the youngest four ages were estimated independently. The von Bertalanffy rate parameter, K, was set to 0.15 $year^{-1}$. The exchange rate of swordfish between regions was set to 0.1 $year^{-1}$.

Results

Figure 2 shows the observed and predicted size distributions in the catch of each fleet. These are the overall distributions over the whole time frame. The distributions that were considered in the estimation procedure were actually quarterly distributions for those quarters within which size samples were taken. The major features of the observed distributions have been captured by the predictions.

The estimated growth curve (Fig. 3) shows some departure from von Bertalanffy in the young ages. The variation in size at age is substantial, but that variation does not increase much with age. Attempts to estimate von Bertalanffy K were not successful. The estimate tended to unreasonably low values, leading to an almost linear growth curve. Therefore K was fixed in the final analysis to 0.15 $year^{-1}$. Estimated recruitment was variable in time but with no major trend (Fig. 4).

The estimated selectivity patterns (Fig. 5) indicate less vulnerability for young (small) swordfish in the eastern Japanese fleets compared to those in the western regions. The Hawai'i estimates show lower vulnerability for younger fish in the north compared to the southern regions.

Wide seasonal variation in catchability was found in all fleets, producing the fuzzy appearance in Fig. 6. Fig. 7 shows the seasonal patterns two years of the time frame. Catchability peaks in the first quarter for fleets in the northern regions and in the second quarter for fleets in the southern regions. The smoothers in Fig. 6 show year to year catchability trends. These are reproduced in Fig. 8 along with points indicating scaled effort deviations. With the appropriate degree of constraint on the catchability time series, the smoothed curve should track trends in the points. Such is not the case when catchability is forced to be constant from year to year, i.e. with infinite constraint on the catchability time series (Fig 9).

Natural mortality was estimated at 0.32 $year^{-1}$. No attempt was made to estimate variability in natural mortality with size or age. Fishing mortality by fleet is shown in Fig. 10 calculated relative to the abundance in the region in which the fleet operates. The Japanese fleets in northern regions show relatively high fishing mortality early in the time frame and declining by around 1970 to levels shown by the other fleets.

Attempts to estimate movement rates were unsuccessful. The estimated movement parameters were unbalanced and caused swordfish in the model to accumulate mostly in only one region with resulting distortion in catchability estimates, that is, with very high catchability estimates in region with very low abundance. Movement was therefore fixed at an exchange rate of 0.1 $year^{-1}$.

Estimated total and adult biomass trends are shown by region in Fig. 11 along with the total biomass that theoretically would have prevailed if there had been no fishing. The trajectories show a dip early in the time frame, particularly in the 1960s in the northern regions. The larger difference in those years between the total biomass curves and the biomass without fishing indicates a larger affect of fishing at that time than in recent years when the reduction in biomass due to fishing has been less than 30% in all regions.

Discussion

A common rule of thumb in stock assessment is that a population exploited at maximum sustainable yield will have its abundance reduced to roughly half of it unexploited state. The results presented here show the population in recent years to be well above 50% of the unexploited levels implying swordfish are not over-exploited and relatively stable at current levels of fishing effort.

As stated above, this is a progress report from early in an assessment project. It is based on an incomplete collection of data from fleets that catch swordfish in the North Pacific. This preliminary analysis has also been simplified by lumping deep and shallow longlining to further reduce the number of fleets to be considered. Nevertheless, the preliminary conclusion of this work is consistent with other swordfish assessments in the North Pacific (Anon, 1999). As shown in Fig. 12, the total biomass trajectory from this work is also comparable to a recently prepared abundance index based on standardized CPUE (K. Yokawa, unpublished) .

MULTIFAN-CL had difficulty in this analysis with estimating the von Bertalanffy growth parameter, *K*, and with estimating movement rates between regions. The difficulty with *K* may stem from the fact that male and female swordfish grow by vastly different growth curves, but MULTIFAN-CL cannot as yet deal with data split by sex and so was presented with composite size sample data. It may be that a combined-sex model of swordfish cannot fit the data well because informative size modes are obscured in the composite data. The same thing could be affecting the estimation of movement rates because in absence of tagging data, the only information on movement would be shifting of size modes from one region to another.

Future plans for this project are to assemble and process for input to MULTIFAN-CL a more comprehensive set of fisheries data for fleets and gear in the North Pacific. More penetrating analysis may be obtained by splitting longline gear by hook depth or perhaps considering hook depth in an effort standardization prior to entry into MULTIFAN-CL. Other possibilities are inclusion of tagging data and possibly further development of MULTIFAN-CL to deal with catch and size sample data split by sex.

References

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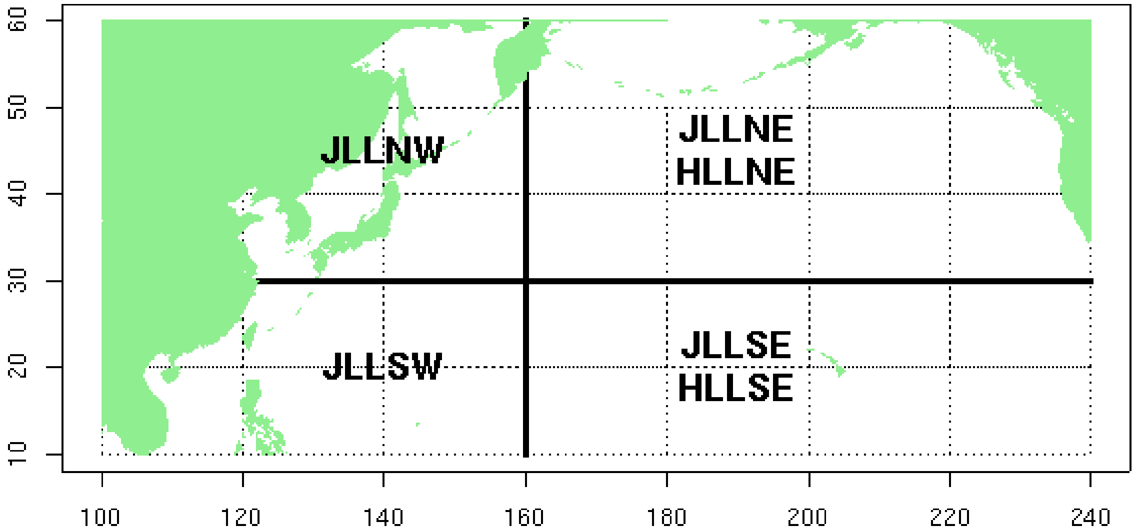

Figure 1. Map showing the four regions and locations of the six fleets considered in the analysis.

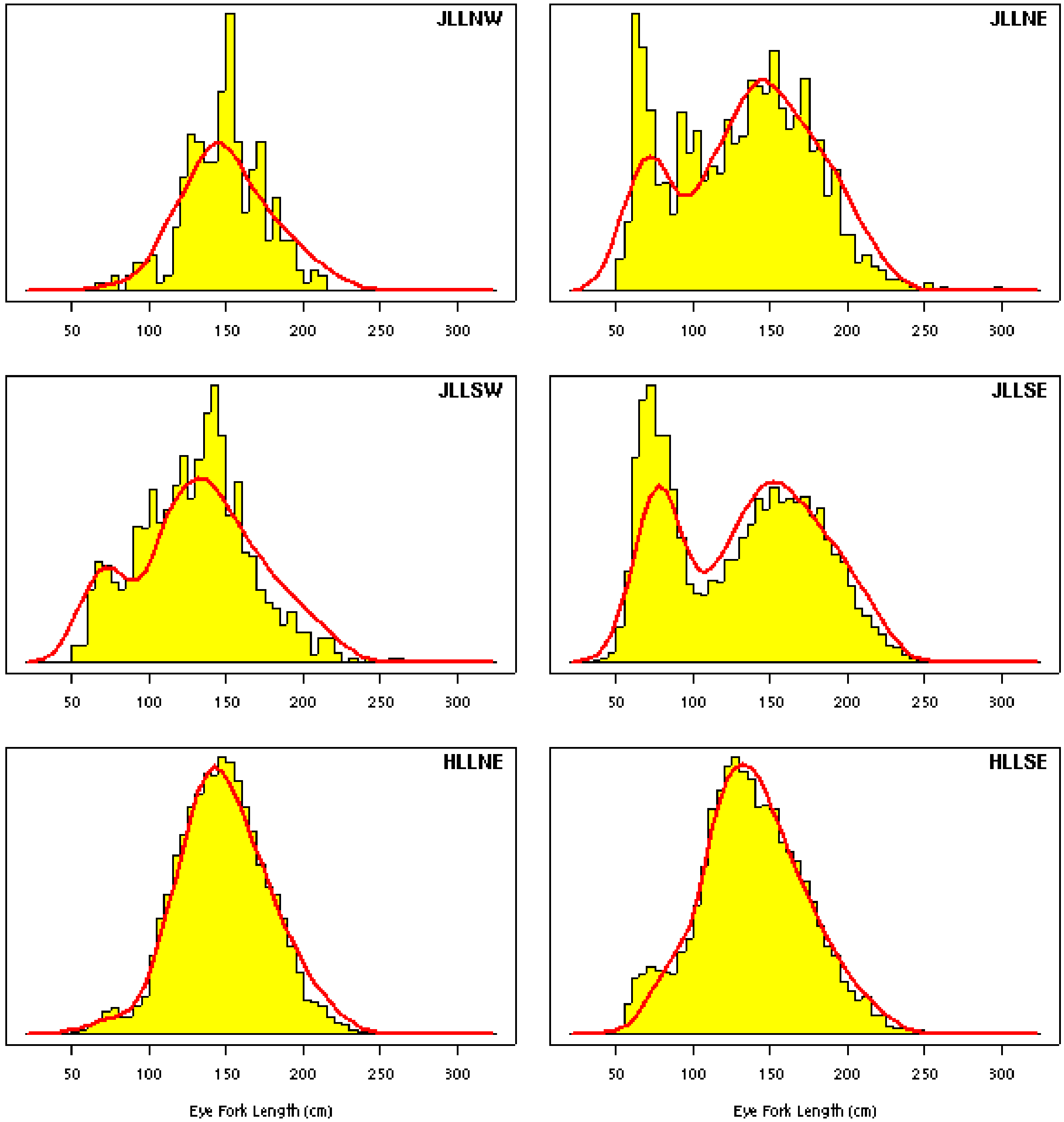

Figure 2. Observed (histograms) and predicted (curves) size frequencies by fleet.

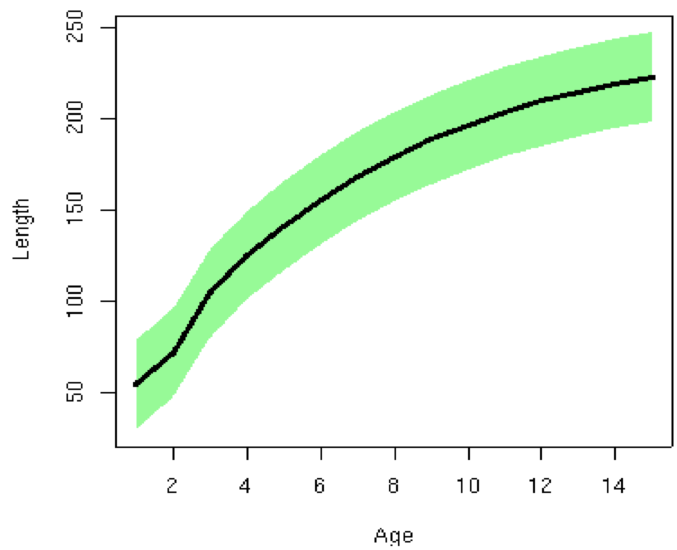

Figure 3. Estimated growth curve, size at ages 1 through 4 estimated individually, size at remaining ages determined by von Bertalanffy curve with growth rate, *K*, fixed at 0.15 $year^{-1}$. Shaded area is approximate 95% range of size variation at age.

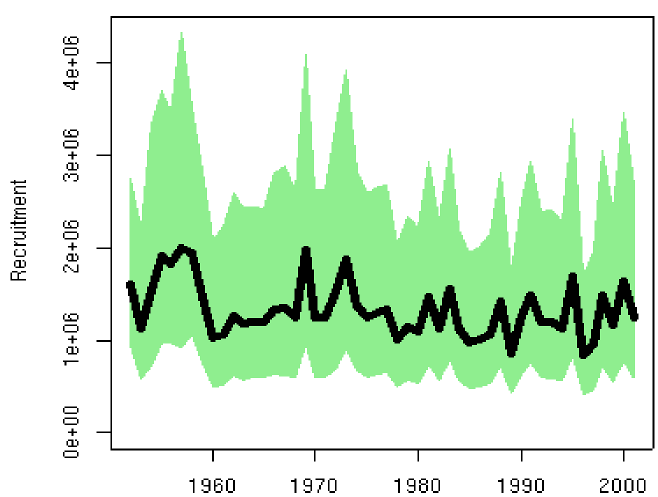

Figure 4. Annual recruitment estimates. Shaded area is approximate 95% confidence region.

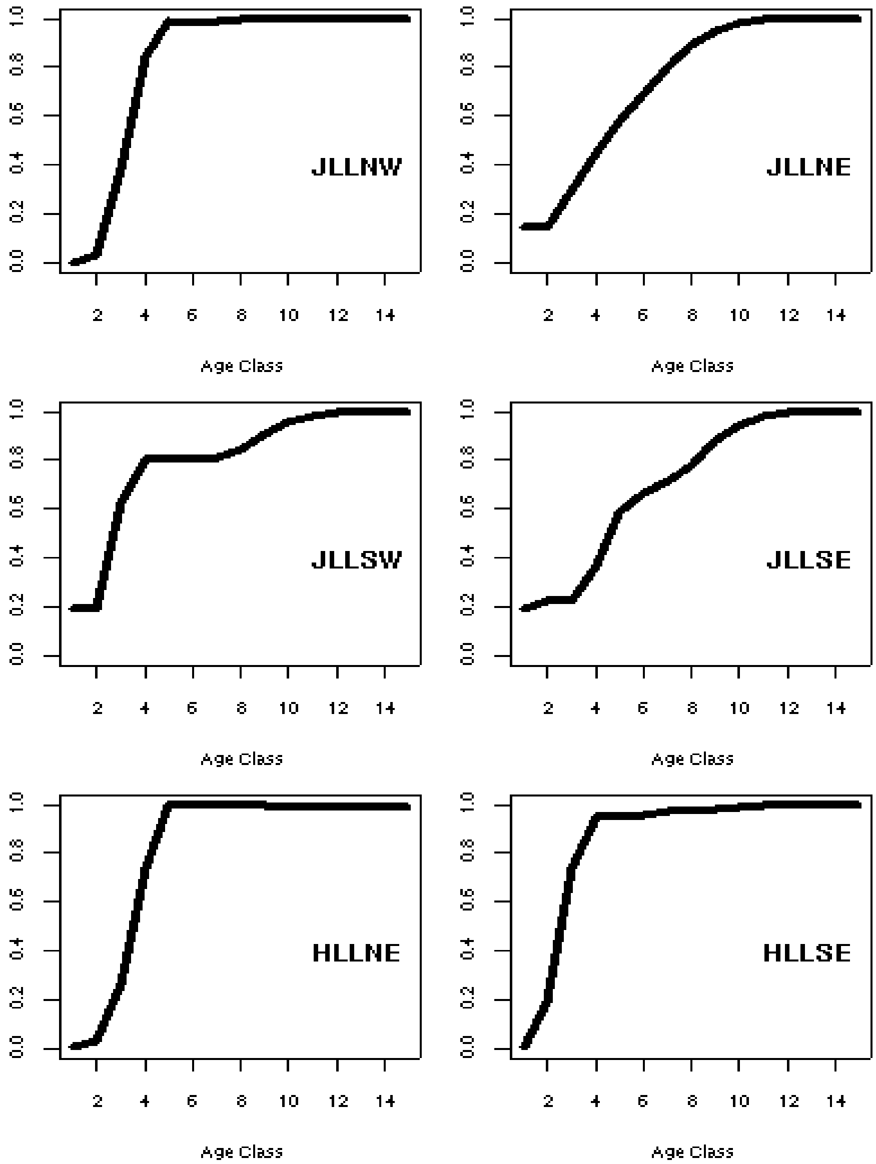

Figure 5. Estimated selectivity patterns by fleet. Selectivity is constrained to be constant for age classes 12 through 15+.

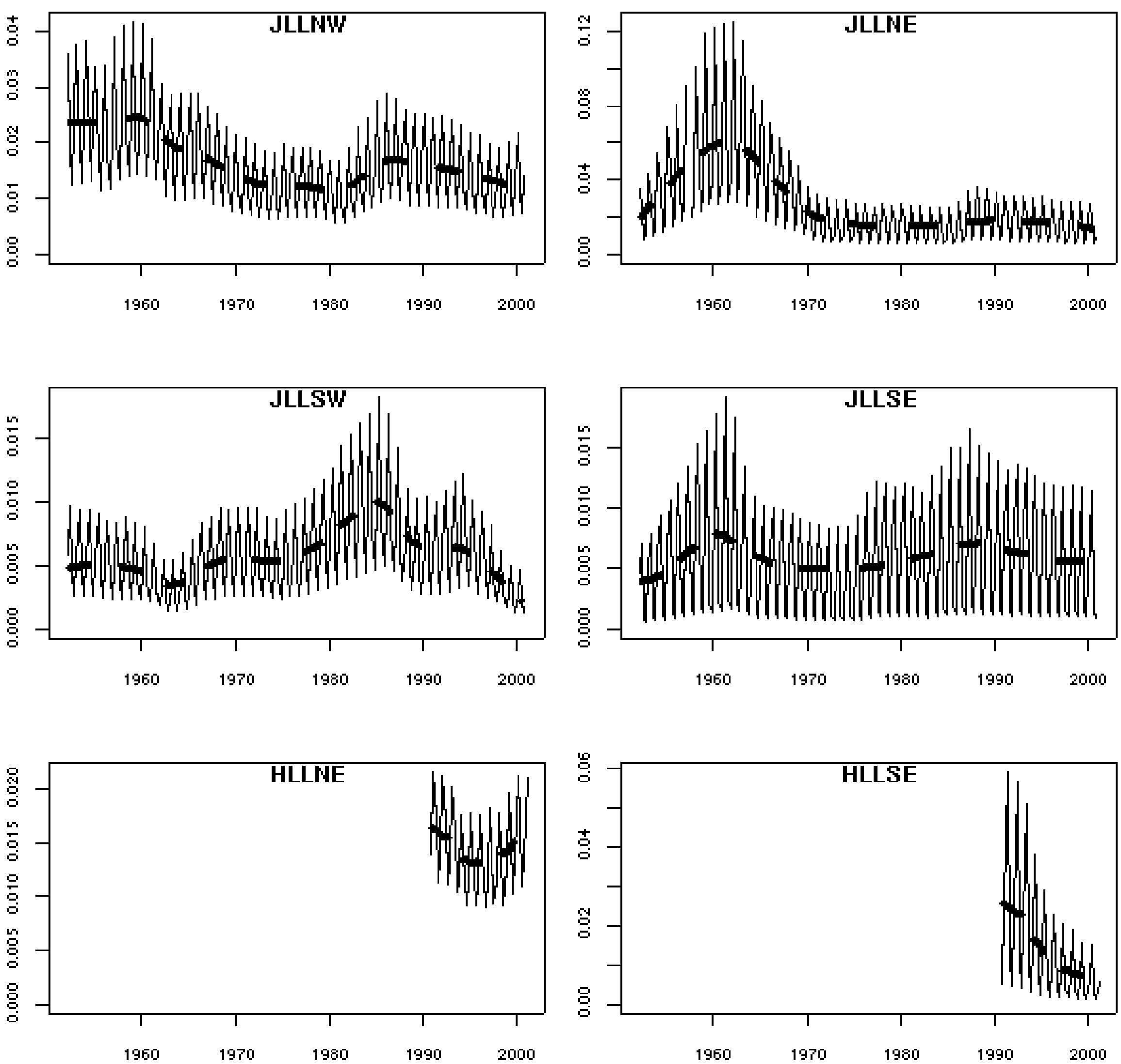

Figure 6. Variation in catchability by fleet showing wide seasonal range with smoothers (heavy dashed lines) showing year to year variation.

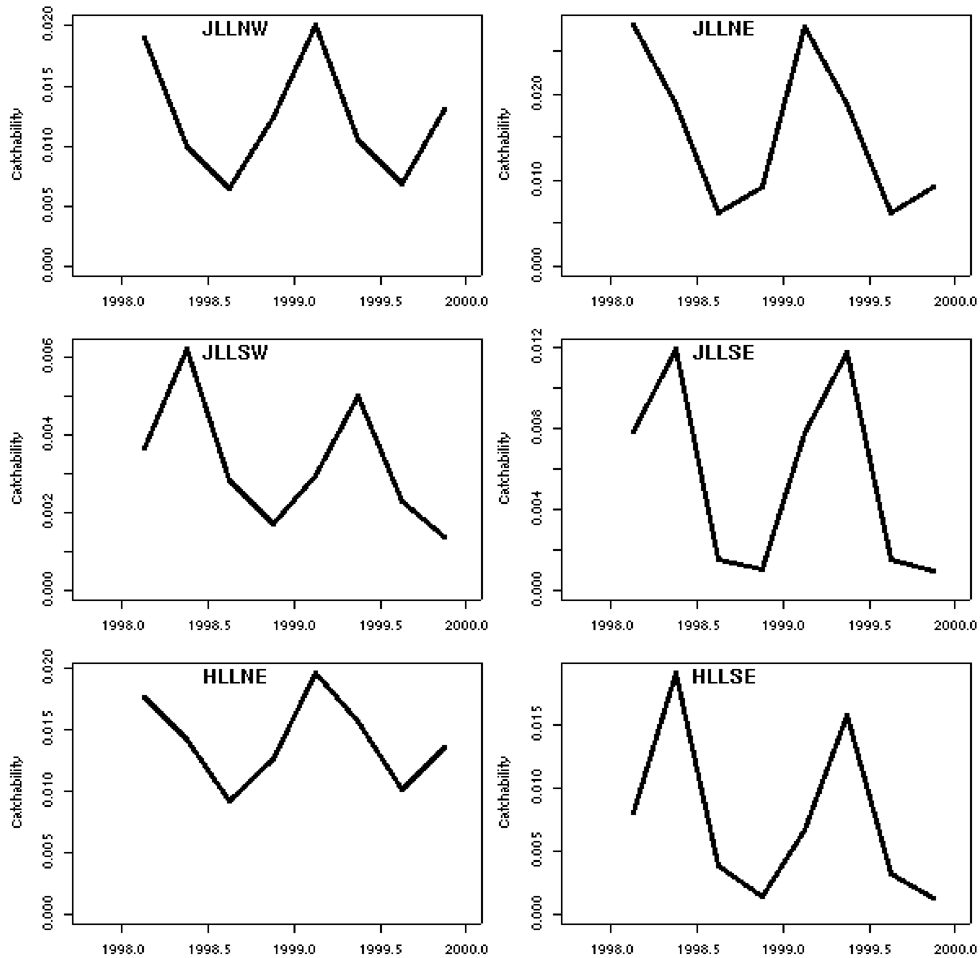

Figure 7. Estimated catchability by fleet in 1998 and 1999 to show seasonality.

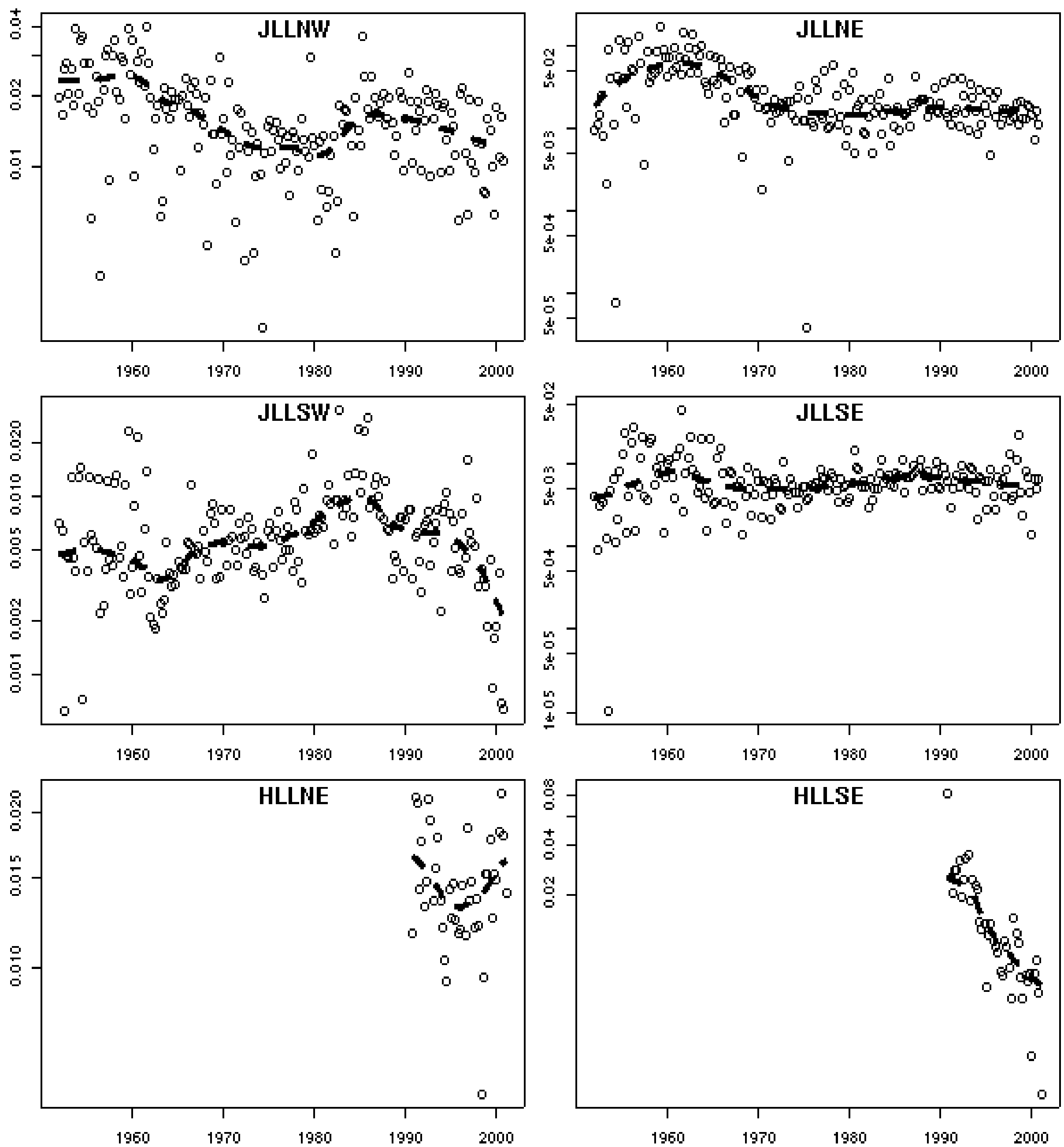

Figure 8. Year to year variation in catchability by fleet (heavy dashed lines) along with effort deviations scaled to units of catchability.

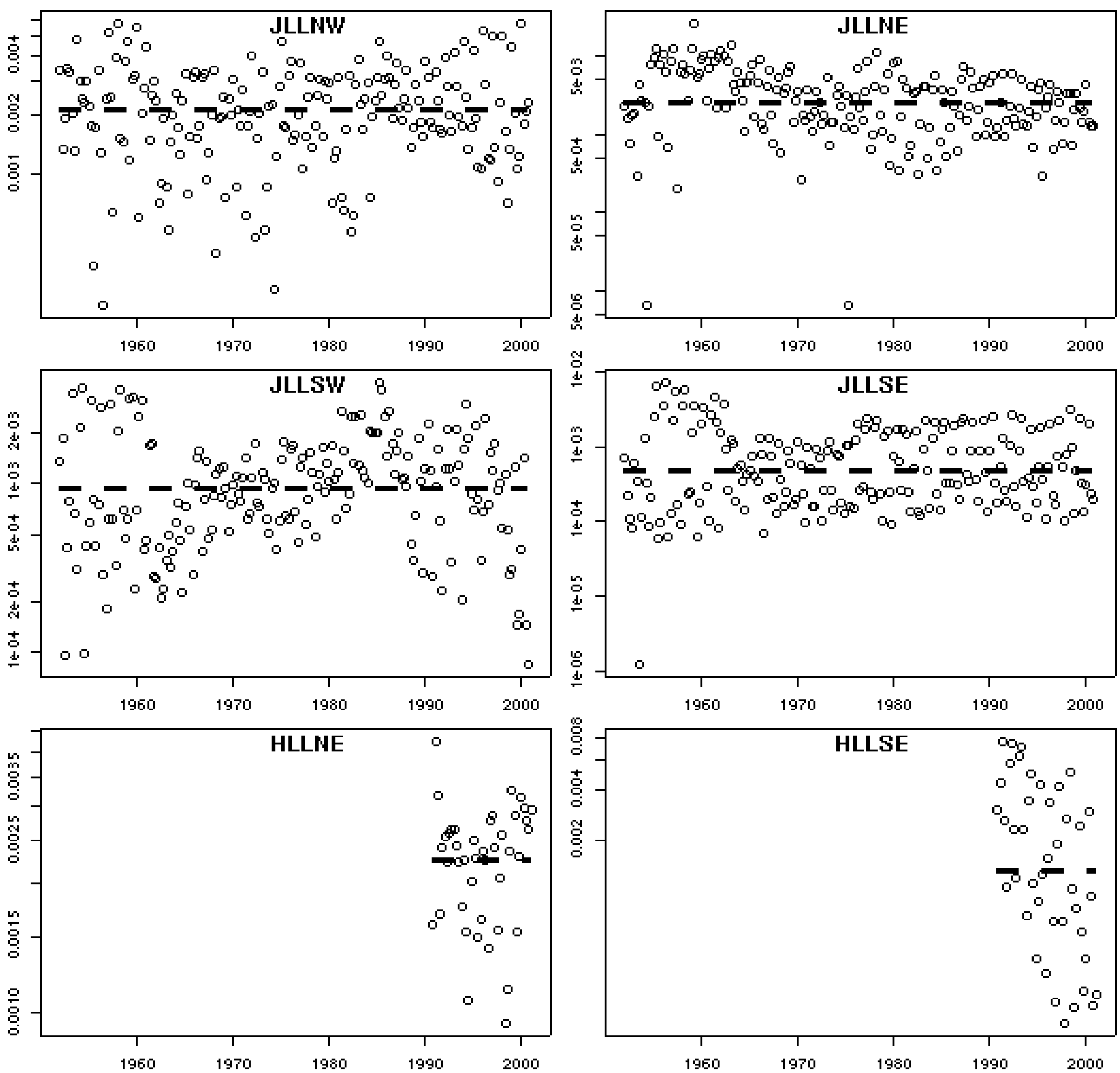

Figure 9. Scaled effort deviations when year to year variation in catchability is disabled..

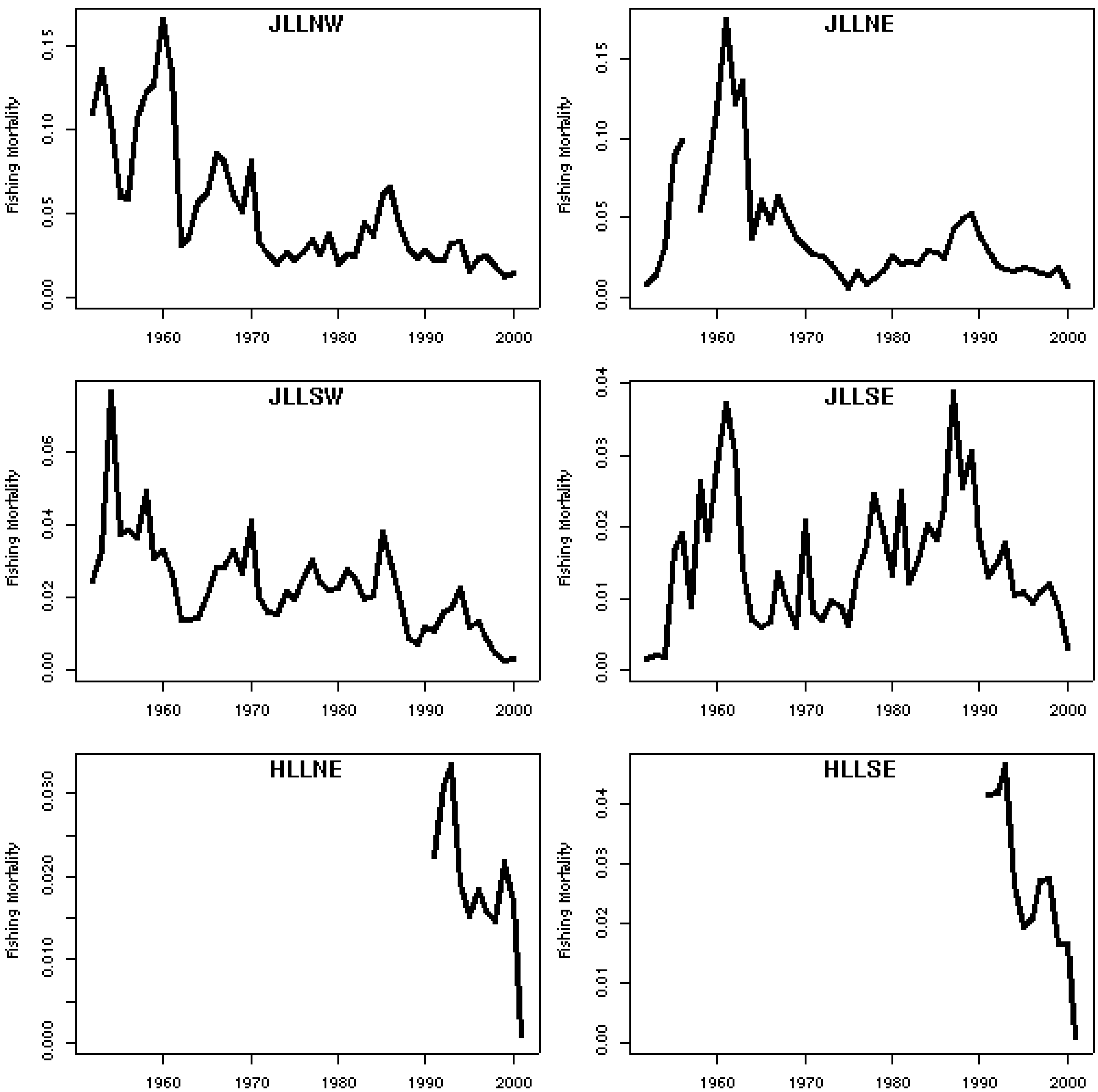

Figure 10. Fishing mortality by fleet given by annual catch as proportion of swordfish abundance (in numbers) at beginning of year in the region in which the fishery operates.

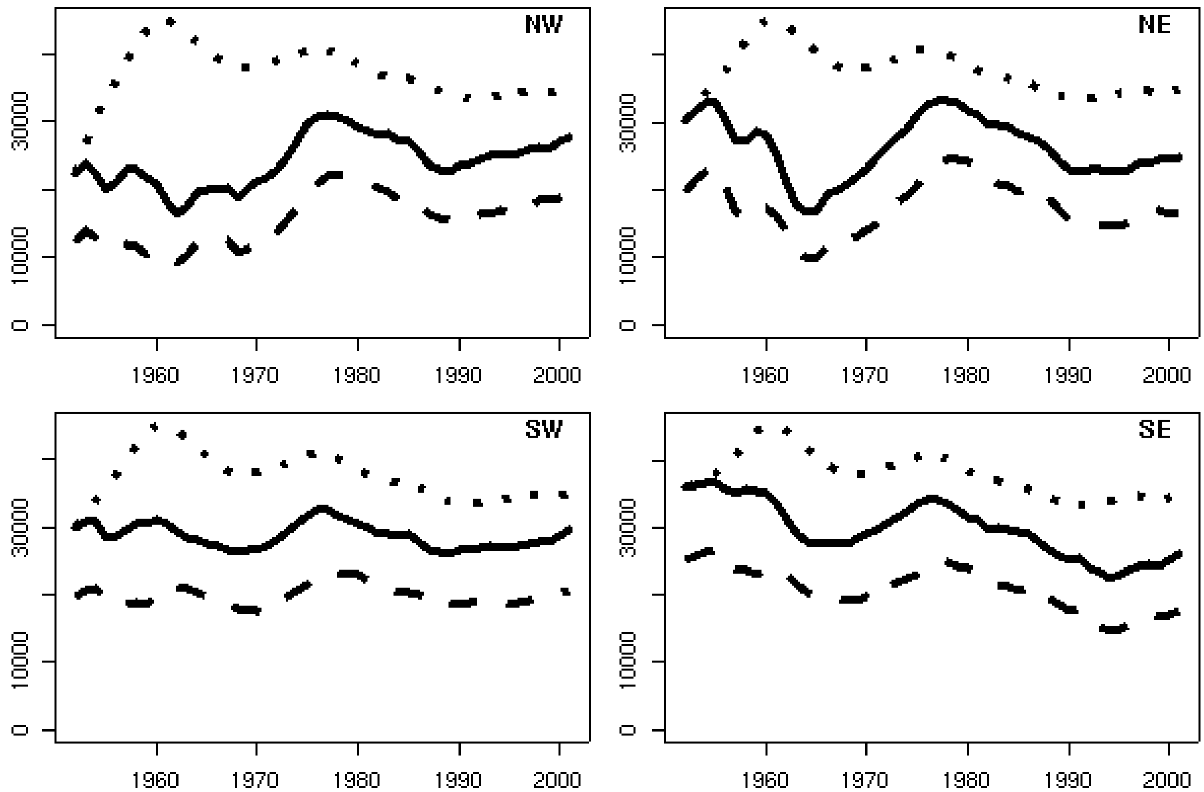

Figure 11. Predicted biomass by region. Solid line – total biomass; dashed line – adult biomass; dotted line – total biomass in absence of fisheries.

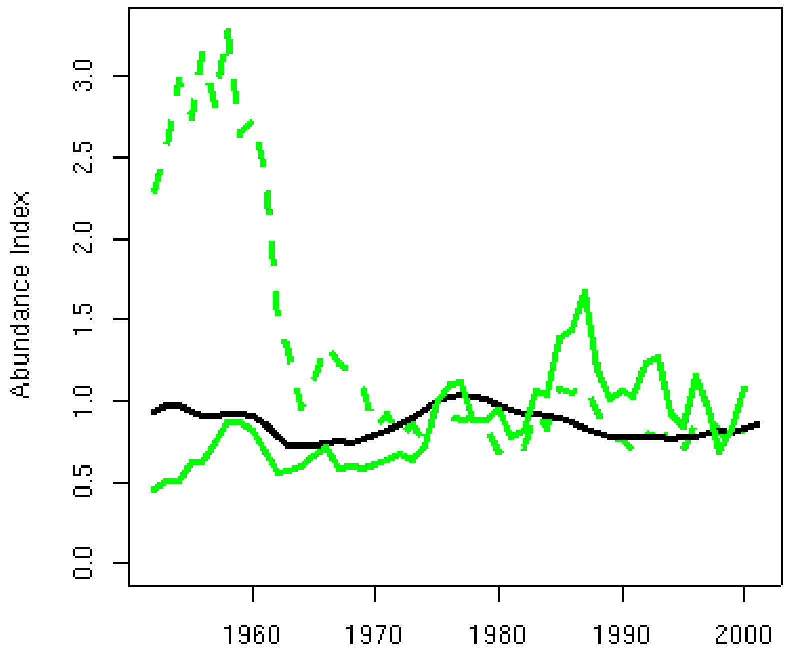

Figure 12. Abundance indices. Raw Japan longline CPUE – light dashed line; standardized Japan CPUE – light solid line; total biomass estimated by MULTIFAN-CL – dark solid line. All indices scaled relative to 1975 value.