Northwest Atlantic Fisheries Organization

Serial No. N4025

NAFO SCR Doc. 98/116

SCIENTIFIC COUNCIL MEETING - NOVEMBER 1998

Jack-knifing a Logistic Model of Biomass Dynamics of the West Greenland Shrimp Stock

by

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Introduction

Northern shrimp (*Pandalus borealis*) occur off West Greenland (NAFO Divisions 0A and 1A-1F) in depths between 150 and 600 m. A multinational offshore fishery began in Davis Strait (SA 1 + Div. 0A) began around 1970. Landings have since increased, to around 70 000 tons in the 1990's. Catch restrictions were first imposed in 1977 and the stock has since been managed by Total Allowable Catch (TAC).

No analytical assessment is available; fishing mortality is unknown. Information available for evaluating the stock status comprises: data from the fishery on catch, effort and standardised catch rates; biomass indices from research surveys; and data on the size composition of the stock (Anon. 1996).

Sequential Population Analysis (SPA) has been tried (Savard *et al.*, 1991), but older ages still cannot be distinguished well enough. A non-age-structured model must therefore be used. Such models are usually of the stock production type. A comprehensive review of biomass dynamic models including references to basic literature are given in Hilborn and Walters, 1992.

For the present article we fitted a logistic production model (e.g. Schaefer, 1954) to two series of biomass indices. One of those indices was a catch-rate index from the commercial fishery, and was itself a composite of four partly overlapping series. As the estimates of such a composite index may have serially correlated errors owing to the effect of errors in the data during the period(s) where the individual series overlap, we used a standard jack-knife (Efron 1982) to examine possible error in the resulting estimates of biomass dynamics parameters.

Materials and methods

Input data

Four standardised catch rate series from different components of the commercial fishery (Hvingel *et al.*, 1998a), covering between them the years 1976–1998, and a series of research trawl survey biomass indices (Carlsson *et al.* 1998) for 1987–98 were used as indicators of stock biomass. Total reported catch in Subarea 0+1 (Hvingel *et al.*, 1998b) was used as yield data.

Model

A standard logistic model of biomass dynamics was used in its differential form:

$$dB/dt = rB_t - (r/K)B_t^2 - C_t$$

where $B(t)$ is biomass (tons) at time t, r (/yr) is 'intrinsic rate of growth', K is 'carrying capacity' (tons), and $C(t)$ is instantaneous catch rate (tons/yr). The parameters (r, K, and a series of yearly values for B) were estimated using ASPIC (Prager, 1994), a program that uses simplex optimisation from randomly chosen starting values. Derived parameters, significant for management, that are also available are the maximum sustainable catch and the associated standing stock and fishing mortality, calculated assuming that the logistic model is appropriate.

Jack-knifing

Standardised indices for the commercial catch rate series for 1976–1998 were estimated by the method described in Hvingel *et al.* 1998a, but leaving out one year of data at a time. The production model was then fitted to the resulting 23 data sets along with the survey series lacking the corresponding year of data. The reported catch data for all years was included in all runs.

Results and Discussion

The maximum sustainable catches, and the corresponding standing stocks, estimated by fitting the logistic model to the data series with, each time, one year's data omitted, are shown in Figure 1. The variation between these estimates is a measure of the uncertainty associated with deductions about sustainable fishing policies based on this kind of model fitting. Salient features of the scatter-plot appear to be:

- Most of the points clustered near a maximum sustainable fishing mortality of about 0.5/yr.

- While (as this implies) the maximum sustainable catch and the corresponding standing stock were in a fairly constant ratio, there was a wide range of values for both. Estimates of the sustainable catch rate ranged from 8.75E4 to 14.58E4 t/yr, and corresponding standing stock estimates from about 15.1E4 to 32E4 t.

- Much of the variability in the estimate of sustainable catch is due to high values associated with analyses which leave out the data from 1985, 1986 or 1987. Omitting either 1990 or 1991 also gave moderately high values of estimated sustainable catch.

- High estimates of standing stock are obtained when data from 1976, 1985, 1986 or 1987 are omitted.

- Leaving out the first value of the series, i.e. 1976, produced a conspicuous outlier, with a low estimate of sustainable fishing mortality (0.282/yr).

- The result obtained from the complete data series is not very central among the scatter of jack-knifed points; instead, it has estimates both of annual sustainable catch (9.6E4 t) and of optimum standing stock 18E4 t) that are close to the lower ends of their ranges.

We have at the moment no quick explanations for these results. Clearly, what we are doing is a complex process, in which omitting a year's data affects the entire CPUE series as well as the fitting of the logistic model. However, the amount of variation in the estimates of sustainable catch raises doubts about the reliability of the results obtained from the entire series of data. In particular, the apparent sensitivity of the estimate of the intrinsic growth rate to the inclusion of the first year's data is a cause for concern.

We therefore suggest that this may be worth investigating further, particularly in two directions: tracking in more detail the effects of omitting data for 1985, 86 or 87 through the processes of standardising the CPUE series and using them as input to the program that fits the logistic model, and examining the apparent sensitivity of the results to the presence or absence of the 1976 data. The former might be studied by systematically varying the data values for those years, in an attempt to find out what features cause them to have their apparent strong effect on the results; the latter might be investigated by making a series of 'doubly jack-knifed' runs, all omitting the 1976 data, but also omitting in turn one other year as well.

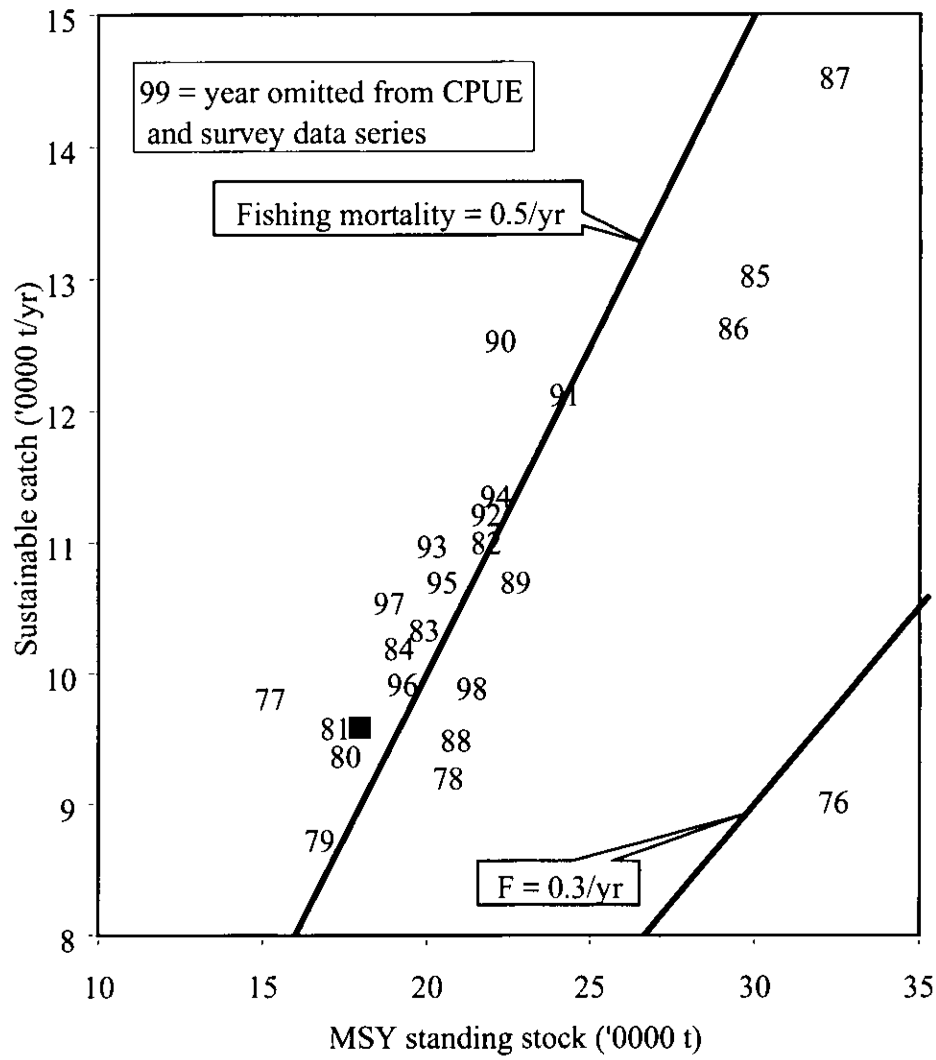

Figure 1. Results of jack-knifing input data used to generate standardised CPUE indices and consequent logistic models of shrimp biomass dynamics.

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