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Correcting CPUE for fishery distribution in the assessment of the Northern Shrimp in Greenland waters.

by

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Abstract

An index of breadth of distribution based on geographic units about 2 n.mi. square was applied to the West Greenland fishery for northern shrimp and used to adjust the unified CPUE index that is taken as a measure of biomass in the annual assessment of the stock. This small-area index was not well correlated with a large-area index of distribution, nor with an index of the *distribution* of survey biomass. The adjusted CPU was better correlated with the survey index of fishable biomass than the unadjusted CPUE index was. When the adjusted CPUE was offered to the stock-production model used for the assessment together with the unadjusted CPUE, the modelled biomass trajectory, as before, followed the unadjusted series. When the adjusted series was offered without the unadjusted series, the modelled biomass trajectory followed the adjusted CPUE series, producing a better fit to the survey biomass series but a larger process error in the model.

Introduction

The West Greenland stock of northern shrimp *Pandalus borealis* is assessed annually. The assessment model in use is a surplus production model (Hvingel and Kingsley 2002) based on the simple Schaefer relationship between biomass and production. It has been in use for 6 years or so. The data series input to the model include two indices of biomass and two indices of removal. The removal indices are a fishery catch series and a series of biomass estimates for Atlantic cod, a significant predator. The biomass indices are a series of estimates of fishable biomass obtained from an annual trawl survey of the offshore grounds and Disko Bay, and a standardised fishery CPUE series.

The single CPUE series input to the model is a weighted composite from four separate standardised series. One is from the early small fleet of offshore trawlers operated by the Kongelige Grønlandske Handel; the others extend from the late 1980s to the present and comprise a Greenland offshore series, a Greenland inshore series, and a series from a Canadian fishery that is prosecuted on a small ground where the W. Greenland shelf extends west of the mid-line.

When the CPUE series and the survey series have diverged, the assessment model has tended to follow the CPUE series closely and largely to ignore the survey series. In the most recent 7 years, the survey biomass estimate has decreased and survey results have shown the distribution of the stock to have been contracting. The fishery has also been shrinking in its distribution, while CPUE has been maintained at relatively constant levels. This has prompted the observation that CPUE measures not biomass but density in fished areas, and if areas that can be profitably fished are contracting CPUE might be maintained even though the stock is decreasing. NAFO Scientific Council therefore recommended in 2009 that *the adjustment of CPUE index series to take account of changes in the area of distribution of the fishery should be investigated.* This document reports on some tentative initial investigations.

Methods

Data series used in the assessment extend back to 1955. However, these long series make the model run very slowly and survey data is only available from 1988 and CPUE data from 1976. In order to have a model that would be tractable for investigative runs, data series were shortened to the most recent 30 years.

Different measures of the distribution of the fishery could be considered. For standardizing CPUEs, hauls are classified by statistical area (Hammeken Arboe and Kingsley 2010). These statistical areas were established *ad hoc* for assessment purposes some years ago, for compartmenting catch and effort data in standardising CPUE statistics. They comprise all the shrimp-fishing grounds in SA1. They have been used as a basis for an index of distribution of the fishery in used in recent SCR Docs to describe its evolution, but for the purposes of the present investigation suffer from the problem that they are few, and therefore yield only a coarse measure of distribution, and of unequal sizes, therefore yielding an uneven measure of distribution: in particular, Area 0 extends over 5° of latitude. The Greenland 'stedkode' system is more uniform, consisting of rectangles 1/8 of a degree of latitude by ¼ of a degree of longitude, but the stedkode quadrats are so large that they are *effectively* of unequal size through lying partly on land or in areas never fished. The basis I eventually picked was the 'FixPos' cell, 1/32 of a degree of latitude by 1/12 of a degree of longitude, and therefore 1 7/8 sea-miles north-south by 2 ½ sea-miles east-west at the latitude of C. Farewell (area 4 11/16 sq. sea-miles), decreasing to 1 ½ miles (3 ¾ sq. sea-miles) at the northern limit of the fishery. (These units were first set up as a basis for the buffered sampling used in laying out the West Greenland survey (Kingsley *et al.* 2004) Hauls were assigned to these map units on the basis of the coordinates of the haul centre.

For a measure of the intensity of the fishery it seemed appropriate to use catches. Number of hauls or haul duration are alike open to the objection that different fleet components have different habits, some making fewer, longer hauls and others more, shorter, ones, and also to the objection that the fishing effort (trawl time) of a large ocean-going trawler is not comparable to that of an eighty-ton coastal vessel. However, a ton of shrimps is a ton of shrimps, whoever catches it.

Therefore, annual catches were accumulated in FixPos cells. As a single index of how widely the fishery was distributed, I used the effective number of cells fished in a year (Simpson 1949):

$$D_y = \frac{\left(\sum_i C_{yi}\right)^2}{\sum_i C_{yi}^2}$$

where C_{yi} was the total catch in year y in cell i, and D_y, the effective number of cells fished, was the resulting index of how widely the fishery was distributed. I didn't put any effort into correcting position data, although there are always some hauls reported in unlikely places. This distributional index is therefore a very slight overestimate.

The distribution indices that first aroused interest were based on larger areas: an index of the distribution of the fishery based on 13 statistical areas, and an index of the distribution of the stock, as shown by the annual trawl survey, based on 6 groups of survey strata. Trajectories of these large-area indices were compared with the FixPos index.

To incorporate the FixPos index with the CPUE series, I simply multiplied the distribution index by the year's standardised CPUE. I used the corrected CPUE only from 1988; before that, it looked as though the fishery was less intense and the resource not fully used.

I ran the model with its shortened series using both CPUE series, only the distribution-corrected CPUE, and only the uncorrected CPUE.

Results

<u>Properties of the data series</u>

The fishery distribution, as indicated by the logbooks available, was restricted for the first 10 years of data. In 1975, apparently, fewer than 6 FixPos cells were effectively fished, and 10 years later the fishery still covered only about 500 sq. sea-miles (Fig. 1). This might be because of incomplete logbook data, or because this was still a small fishery, being prosecuted by a small fleet of trawlers. However, in the late 1980s the fishery was evidently transformed. According to the logbook data, both the effective size of the offshore fleet (Hammeken Arboe and Kingsley 2009) and the effective fished area increased by a factor of about 6 between 1985 and 1990 (Fig. 1). (In response to an evident need for management information independent of the fishery, the trawl survey in offshore areas north of Julienehåb Bugt was started in 1988 and extended in 1991 into Disko Bay and in 1994 south to C. Farewell.) Since 1990, the effective fished area has remained in the range 600–900 cells, out of some 11 400 in the survey area between 150 and 600 m deep and about 9600 that occur, overall, in logbooks.

A spread index has been calculated for the survey results as a means of summarising one aspect of the distribution of the stock as shown by the survey (Kingsley 2008, Ziemer and Siegstad 2010). Both the survey spread index and the FixPos fishery distribution index generally increased from 1996 to about 2002–04 and both have generally decreased since then, but, while the correlation is at least positive, the survey spread index and the index of fishery distribution are not closely correlated (Figs 1, 2).

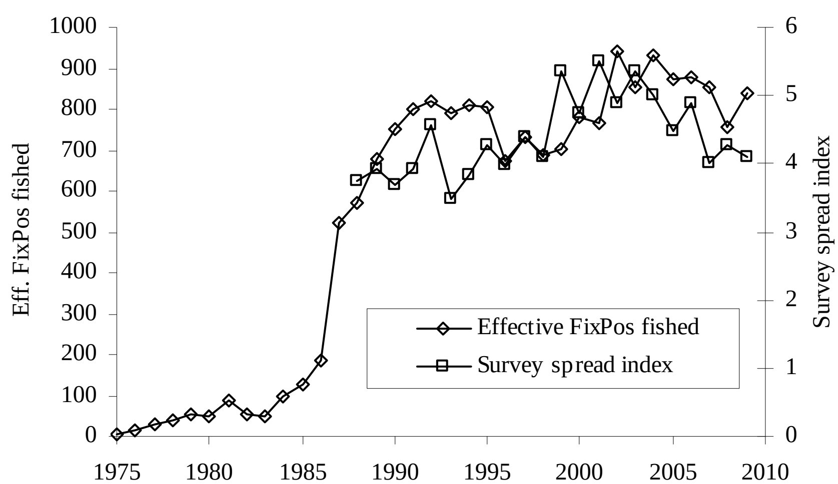

Figure 1. Northern shrimp in West Greenland: indices of fishery distribution 1975–2009 and of the breadth of distribution of the stock as shown by trawl survey, 1988–2009

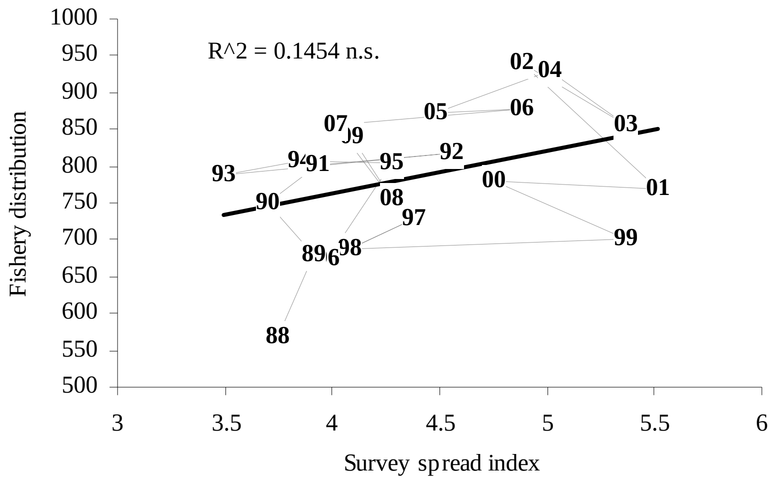

Figure 2. Northern shrimp in West Greenland: indices of fishery distribution based on FixPos cells and of the breadth of distribution of the stock as shown by trawl survey, 1988–2009.

I also compared the trajectory of the 'FixPos' index of distribution with that of a distributional index for the fishery based on statistical areas, which has been presented for several years in the analysis of the fishery (Fig. 3).

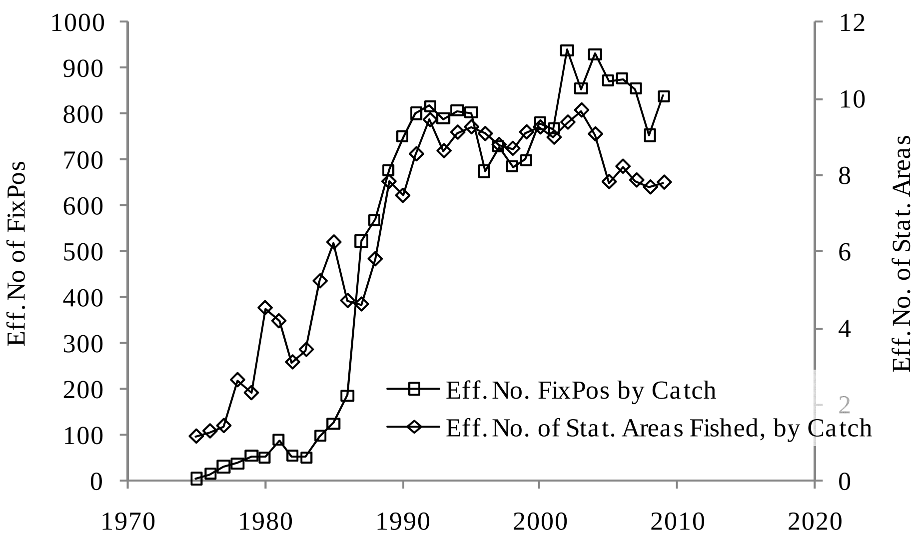

Figure 3: Northern shrimp in West Greenland: Distribution indices for the Greenland fishery based on statistical areas and on FixPos cells, 1975–2009.

The fishery distribution index based on FixPos is not closely correlated with the fishery distribution index based on statistical areas (Figs 3, 5), while the latter *is* correlated with the survey index. I infer that the two large-area indices agree, because both are reporting the abandonment of the (smaller) southerly areas and a contraction of the stock and the fishery into a core range, while the FixPos index differs because it is not only affected by the large-area distribution, but also by the breadth of distribution *within* the large areas, and this has not been constant. Within statistical areas, the breadth of distribution of the fishery has varied a great deal over time, and not at all synchronously. The distribution of the fishery as shown by large-area indices has contracted in recent years. However, the FixPos index shows a widening of distribution from about 700 cells in 1998–99 to about 900 in 2002–04. This widening, not evident in the large-area fishery series, coincided with a period of increase in the unadjusted

CPUE, and the two together produced a large increase in the adjusted CPUE that also coincided with a great increase in the survey biomass series (Fig. 4). The recent contraction in the large-area fishery series and the survey distribution series has not been evident in the FixPos distribution series.

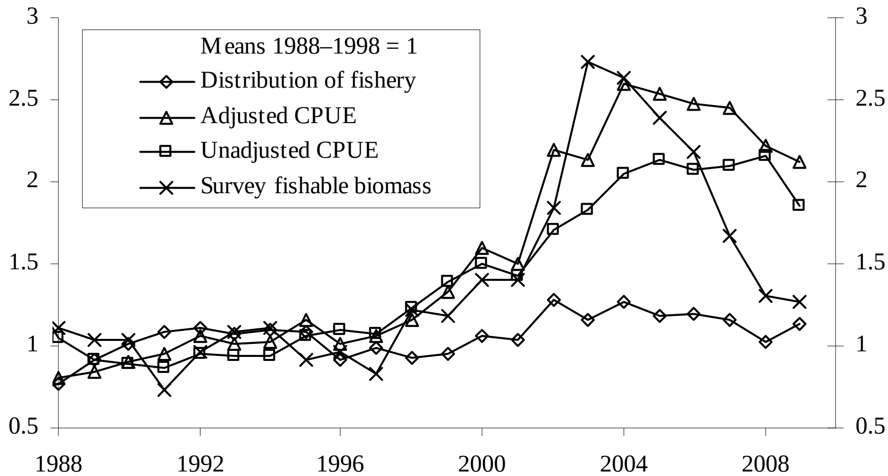

Figure 4. Northern Shrimp in West Greenland: indices of biomass and distribution, 1988–2009.

Over the period considered, the survey index of fishable biomass was quite highly correlated with both CPUE and adjusted CPUE, slightly better with the adjusted CPUE (r = 83.5%) than with the unadjusted (r = 78.6%).

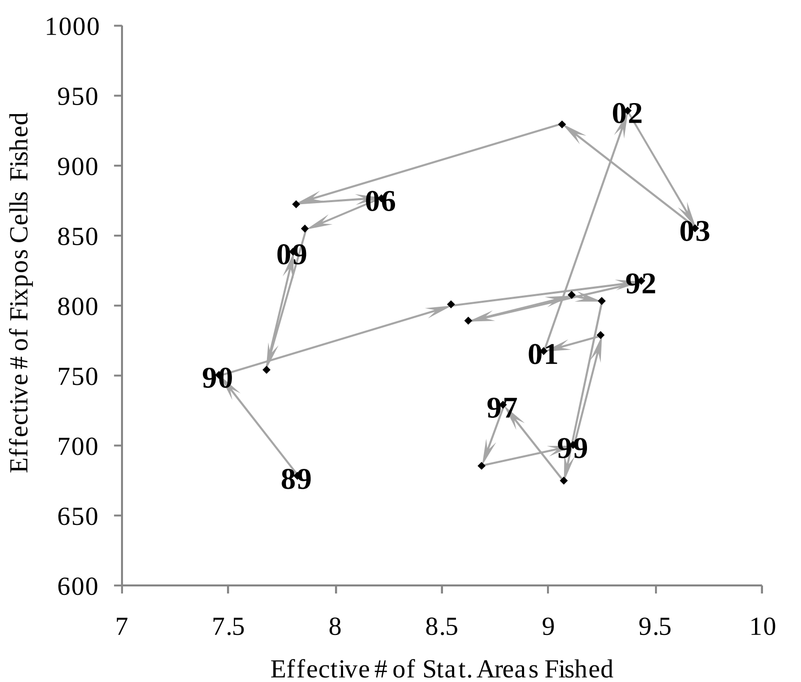

Fig. 5: Northern shrimp in West Greenland: small-area and wide-area indices of breadth of distribution of the fishery, 1989–200.

<u>Results from running the assessment model</u>

When the uncorrected CPUE was offered alone the modelled survey biomass tended to follow it and to ignore the survey series (Fig. 6, Table 1). The CV for the CPUE series was only 4%, and for the process error 7.6%, while the survey biomass CV was 21.4%. The assessment model has behaved in this way for a number of years, and it seems likely that the model follows the CPUE series and ignores the survey because large swings in the survey result are not consistent with the model's wish for orderly population dynamics.

Table 1: Northern shrimp in West Greenland: median values of CVs (1/sqrt precision)

	Process	CPUE	Adjusted CPUE	Survey
CPUE only	7.60	4.0	N/A	21.4
Corr. CPUE only	11.37	N/A	5.3	20.8
Both CPUEs	7.56	4.48	13.67	21.1

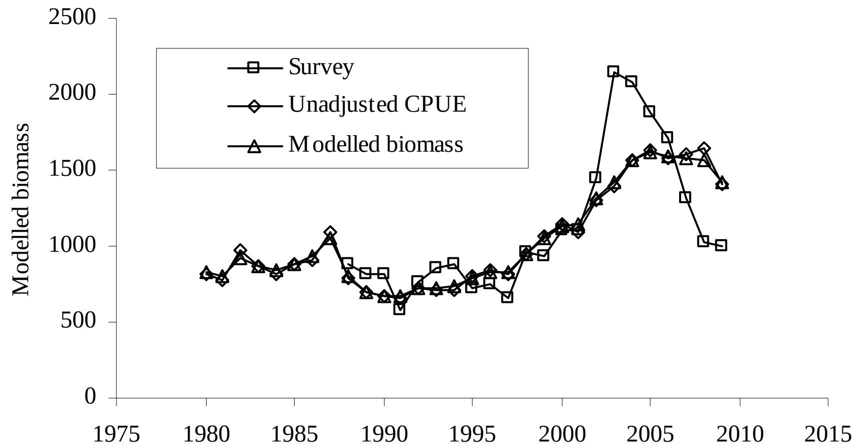

Figure 6. Northern shrimp in West Greenland: biomass trajectories fitting to the unadjusted CPUE series as well as survey data.

When the adjusted CPUE series was added, there were only slight changes. The CV for the unadjusted CPUE increased slightly, while the process error and the survey CV both decreased slightly (Table 1). I.e. the adjusted CV was able to persuade the model to take just a little bit more notice of the survey series—but not much, and was not even very successful in getting the model to notice itself. The model still paid most attention to the unadjusted CPUE, because this also allows it to fit a small process error (Fig. 7). The modelled biomass trajectory changed little: B_{msy} increased, and Z_{msy} decreased, by about 6% (Table 2).

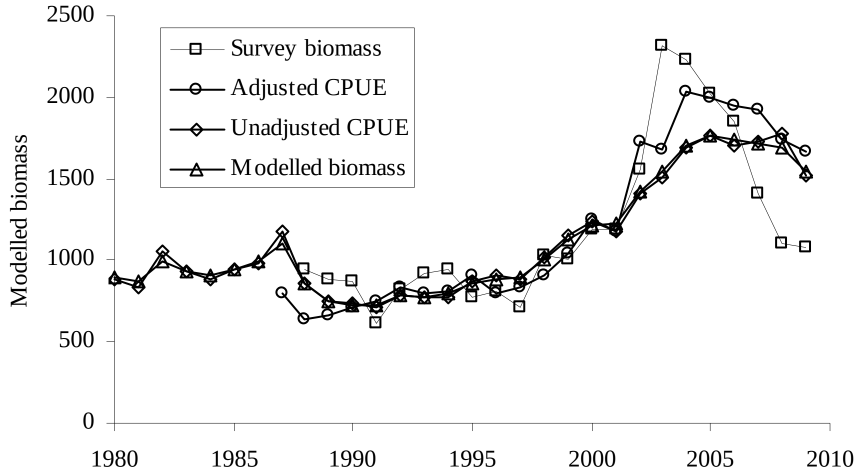

Figure 7. Northern shrimp in West Greenland: biomass trajectories fitting to both adjusted and unadjusted CPUEs as well as survey data.

When the unadjusted CPUE was taken away, and the stock trajectory fitted only to the adjusted CPUE and the survey, the model switched its allegiance to the adjusted CPUE series (Fig. 8.). Since that has slightly better correlation with the survey, the survey CV decreased a little bit, while the process error increased markedly (Table 1)—evidence that it is the low process error that attracts the model to the CPUE series overall.

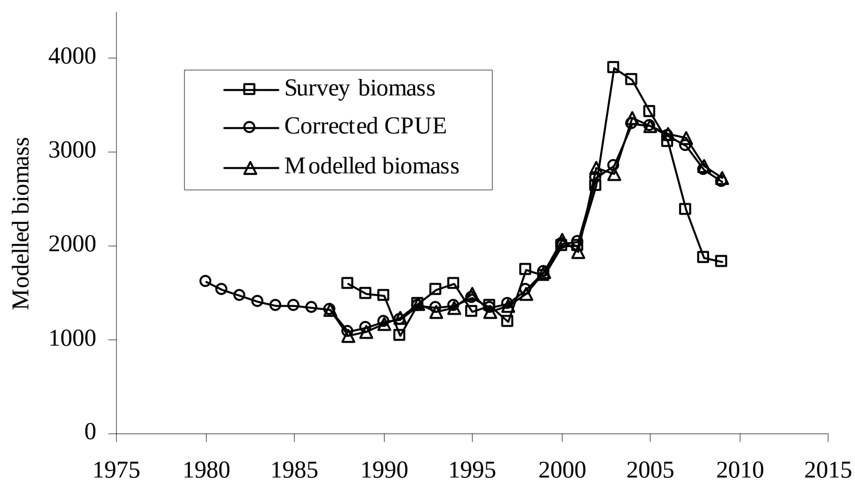

Figure 8. Northern shrimp in West Greenland: biomass trajectories fitting to adjusted CPUE series as well as survey data.

The modelled relative biomass was affected by changing the CPUE series; in particular, the *increase* in adjusted CPUE better fitted the increase in survey biomass, especially between 2000 and 2004. However, while the relative trajectories were similar, there was a considerable change in the estimates of most of the population-dynamic parameters that govern the biomass trajectory. There was not much change in the MSY, this being governed by catches that the stock has been able to tolerate in the past, but the model now estimated a much larger, but less productive, stock. The values on the biomass axis of Fig. 8 are quite different from those of Figs 6 and 7. However, we have always recognised that the estimates of absolute biomass are not reliable, and have put more faith in trajectories of relative biomass.

Table 2: Northern shrimp in West Greenland: indices of stock dynamics estimated by stock-production modelling with one or both of two CPUE series.

	Adjusted CPUE only	Both CPUE series	Unadjusted CPUE only
MSY	155.8	156.7	159
B_{msy}	1338	1419	2405
Z_{msy}	13.49	12.77	9.3
Survey catchability	26.5	24.71	18.5

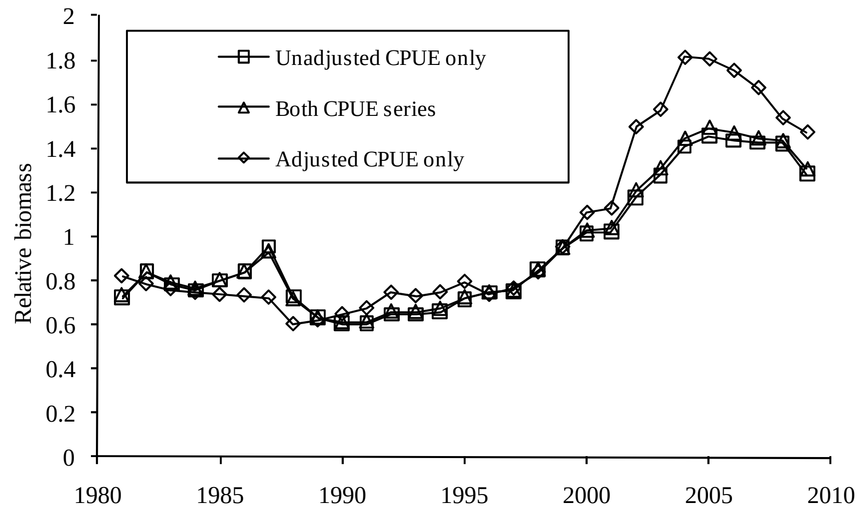

Figure 9. Northern shrimp in West Greenland: modelled trajectory of relative biomass (B/Bmsy) when fitting to one or both of an unadjusted and an adjusted CPUE series.

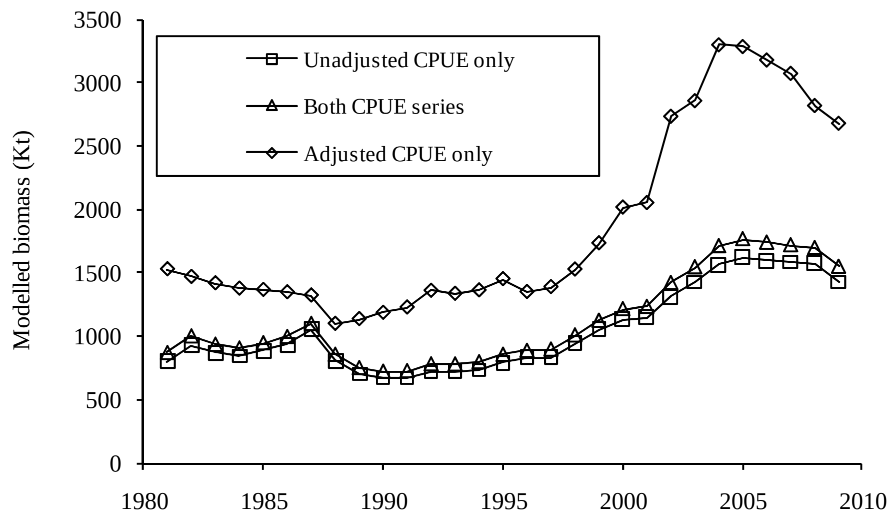

Figure 10: Northern shrimp in West Greenland: modelled trajectory of absolute biomass when fitting to one or both of an unadjusted and an adjusted CPUE series.

The increase in the adjusted CPUE around 2000, not counterbalanced by a corresponding decrease in the most recent years, produces a more optimistic estimate of the present state of the stock relative to B_{msy} (Fig. 9), and when combined with the different estimate of B_{msy} itself, a very different estimate of the present biomass.

Conclusions

1. A first conclusion based on comparing the different indices of distribution is that the large-area indices might not be quite faithful in presenting the distribution of catches, and the analysis of fishery distribution is more complex than it at first appeared. The breadth of distribution *within* large areas also varies.

2. The adjusted CPUE correlates a little bit better with the survey biomass estimate than the unadjusted CPUE does; when offered to the assessment model it monopolises the model fit just like the unadjusted series, but does allow a slightly better fit to the survey series. The model desires orderly stock dynamics.

3. The model runs with the adjusted CPUE series, and produces coherent results, although not quite what was looked for: the adjusted series increased greatly when survey biomass increased, but has not decreased fully in step with the decrease in survey biomass, resulting in a more optimistic rather than a more pessimistic view of the present state of the stock.

4. It's an interesting exercise; the results were not quite what might have been expected; might be worth taking further.

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