Northwest Atlantic Fisheries Organization

Serial No. N6364 **NAFO SCR Doc. 014/062**

NAFO/ICES *PANDALUS* ASSESSMENT GROUP—SEPTEMBER 2014

Revised treatment of cod survey data in assessing the West Greenland stock of *Pandalus borealis*

by

Michael C. S. Kingsley

Pinngortitaleriffik, Greenland Institute of Natural Resources
Box 570, DK-3900 Nuuk, Greenland

Summary

Introduction

The Atlantic cod *Gadus morhua* is a significant predator on the Northern shrimp *Pandalus borealis*. The West Greenland stock of *P. borealis* is assessed annually using a quantitative surplus-production model. The stock dynamics of the model include a term for predation by cod, which is considered to vary with changes in the biomass of the offshore cod stock and its distributional overlap with the stock of shrimps.

The biomass of cod has been estimated over time in several ways giving rise to several series of estimates. A virtual population analysis exists for 40 years from 1950 to 1989 (Buch et al. 1994). A consistent series of research trawl survey estimates by the German *Walter Herwig* runs from 1982 to date (Fock 2014). The German surveys are carried out too late in the year to provide data for the current year's assessment. Another research trawl survey series by the Greenland *Paamiut*, carried out earlier in the year, runs from 1993 to date. The gear used in the Greenland surveys was a *Skjervøy* trawl until 2004 and a *Cosmos* from 2005 on (Wieland 2005).

Previous practice has been to consider the VPA estimates as benchmark, and the German survey as reliable, as it targets groundfish while the Greenland survey principally targets shrimps. The overlap between the VPA and the German survey has been used to develop a factor for correcting the German survey into a continuation of the VPA series, and the relationship between the German and the Greenland surveys has been used to develop a correction so that the present year's Greenland estimate can be used for the current year's assessment. The resulting cod series has been multiplied by an 'overlap factor' (Global Index of Collocation, Bez and Rivoirard 2000) to calculate an 'effective cod' series which has then been incorporated into the assessment model as though free from uncertainty.

STACFIS has recommended for the West Greenland assessment that the Greenland survey estimate should be explicitly included in the assessment model. This has now been done and this document describes how.

Methods

The cod-biomass-index data has been considered to comprise four independent series: the VPA, the German survey, the Greenland *Skjervøy* survey and the Greenland *Cosmos* survey. Each is considered a linear index of an unknown 'True Cod' biomass, so that a predicted value for the index would be the True Cod biomass multiplied by a scaling factor:

$$\ln(I_{i,y}) = \ln(T_y \times f_i) + \varepsilon_{i,y}$$

where $I_{i,y}$ is the observed value of the i^{th} index in year y, T_y is the True Cod biomass in year y, f_i is a scaling factor between the i^{th} index and the cod biomass, and the values of ε_i are Normally distributed with zero mean and variance σ_i^2.

In the revised practice introduced in 2014 all four series are given to the assessment model to be fitted at the same time as the two shrimp biomass series—trawl survey and fishery CPUE—and the predation estimates (Table 1). A separate overlap series (Bez and Rivoirard 2000; Table 1)is also given to the model to be multiplied by the estimated True Cod biomass to create an Effective Cod series that enters a functional equation relating the rate of predation to shrimp biomass and cod biomass.

Table 1: *Pandalus borealis* in W. Greenland: cod biomass index series ('000 t) and overlap series used in the assessment model to fit a series of effective (i.e. predator) cod biomasses, with the median estimates of the resulting series.

	VPA	ICES	Greenland Skjervøy	Greenland Cosmos	Overlap	Effective Cod (median estimate)
1985	51.7	19.00			0.482	20.4
1986	38.4	38.90			0.510	23.3
1987	466.7	316.50			0.604	289.2
1988	481.2	323.40			0.618	303.3
1989	403.2	202.30			0.370	136.6
1990		21.10			0.289	10.0
1991		3.40			0.313	1.8
1992		0.36	0.25		0.523	0.3
1993		0.21	0.20		0.646	0.2
1994		0.07	0.05		0.599	0.1
1995		0.03	0.16		0.483	0.1
1996		0.20	0.11		0.280	0.1
1997		0.14	0.06		0.490	0.1
1998		0.07	0.10		0.390	0.1
1999		0.14	0.05		0.496	0.1
2000		0.32	0.36		0.643	0.4
2001		1.30	0.60		0.462	0.7
2002		1.22	1.86		0.278	0.7
2003		1.29	1.33		0.398	0.9
2004		3.43	2.39		0.257	1.3
2005		13.60		63.95	0.074	2.8
2006		81.06		24.51	0.220	21.7
2007		86.59		28.49	0.139	14.7
2008		31.81		28.48	0.156	8.3
2009		2.01		3.60	0.602	2.5
2010		10.58		8.13	0.315	5.3
2011		14.33		18.73	0.888	24.0
2012		100.80		37.10	0.305	38.8
2013		114.35		85.81	0.206	37.2
2014				114.78	0.211	44.3

The surplus-production model is fitted by Bayesian methods so it is necessary to provide prior distributions for parameters and variables. The scaling factors for the VPA series and for the two Greenland series are given priors uniform in log. space between exp(- 3) and exp(3). The scaling factor for the German survey is fixed at 0.6, chosen to result in a VPA scaling factor close to 1 (since the VPA has always been thought of as the 'true' value). The precisions (reciprocal of variance) of the ε are all given uninformative priors Gamma(0.01, 0.01).

The unknown True Cod series was eventually given two-step priors. The annual True Cod values were given independent log.-Normal distributions each with its own median and its own precision. All the precisions were then given the same uninformative Gamma(0.01,0.01) prior, and the medians were given a common Normal prior with precision 0.04. The mean of this prior was then given its own Normal prior with zero mean and a precision distributed as Gamma(0.01,0.01). The coding will be clearer than this description:

```
for (i in 1:Present.Year)
{  Past.cod[i] <- True.cod[i] * Overlap[i]
   True.cod[i] ~ dlnorm(T.c.median[i],T.c.prec[i])
   T.c.prec[i] ~ dgamma(0.01,0.01)
   T.c.median[i] ~ dnorm(T.c.overall.median,0.04)
}
T.c.overall.median ~ dnorm(0,T.c.overall.prec)
T.c.overall.prec ~ dgamma(0.01,0.01)
```

Results

The cod biomass has ranged over several orders of magnitude in recent decades, and setting suitable priors for the True Cod series gave some trouble. If they were too uninformative, they hindered the sampling of the posterior distribution. The eventual choice of multi-stage uninformative priors seems to be working and gives smooth updating. The calculated effective cod series for 2014 was close to the provided series for 2013 (Figure 1).

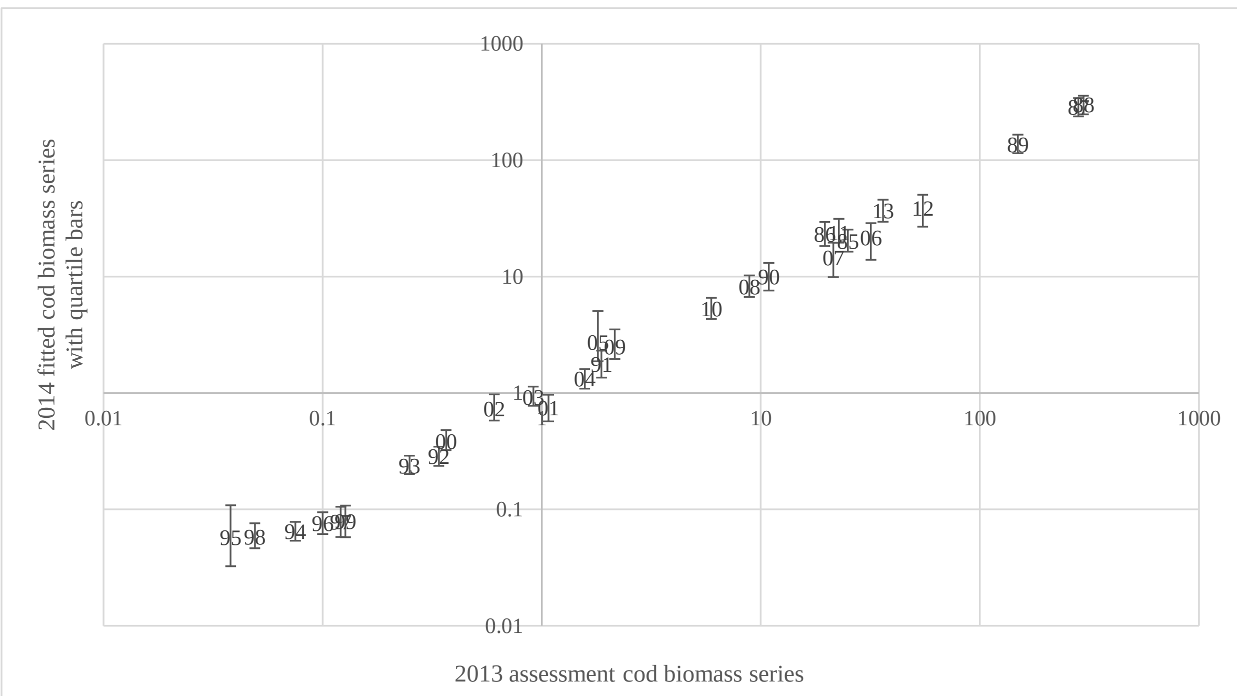

Figure 1: *Pandalus borealis* in West Greenland: endogenous estimates of 'effective' cod biomass fitted in a stock-production assessment model to four series of biomass indicators vs exogenous estimates provided to the model in 2013.

Scaling factors and precisions for the different series are updated to well defined posterior distributions.

Table 2: *Pandalus borealis* in West Greenland: posterior estimates of scaling factors and fit CVs for fitting four cod-biomass indicator series to a fitted series of true cod biomass values.

	scaling factor (quartiles)			CV (%) (quartiles)		
	lower	median	upper	lower	median	upper
VPA	0.81	0.99	1.23	32.0	43.6	61.2
Walter Herwig	0.60	0.60	0.60	36.9	50.5	65.6
Paamiut--Skjervøy	0.37	0.44	0.52	50.8	67.3	83.9
Paamiut--Cosmos	0.41	0.50	0.62	55.2	74.0	95.2

The ratio of the median estimates of the scaling factors for the two trawls used by the *Paamiut* is 0.88, which is different from the value of 0.65 used before.

The posterior estimate of the CV of the Paamiut Cosmos survey is rather large and its scaling factor is also not very well known, partly because the series is still only twelve years long. And the present-year estimate is only derived from the most recent Cosmos survey. This has always been the case; in the past we have just ignored its uncertainty; but now, the estimate of the current year's cod biomass ends up with a relative i.q.r of 107%. This is expected to make it harder to predict the stock status at the end of the current year, and with it, the risks associated with management options in future years. How big a problem that will be depends on how the cod stock evolves. In 2013, that year's effective cod stock at 36.2 Kt had no uncertainty; in 2014, 44.3 Kt has a relative i.q.r. of 94%. The estimated amount eaten in the current year went from 15.4 Kt with i.q.r. 154% in 2013 to 15.5 Kt with i.q.r. 230%—so although the predation relationship is very uncertain, the additional uncertainty as to the biomass of cod is not helping. In 2013 the model predicted a year-end relative biomass of 109% with relative i.q.r. 34.6%, and in 2014 the relative i.q.r. on 97.3% is 38.7%, 12% larger.

Comments and Conclusions

This procedure for fitting a cod biomass series to survey observations will be handled a bit differently by the assessment model from the previous procedure of simply handing it a fixed series calculated in advance. The assessment model will be capable of adjusting the fit of the cod biomass to the cod surveys, if by doing so it can improve the overall fit to all the data through the cod-biomass effect on predation, the effect of predation on shrimp biomass and consequently the fit of shrimp biomass to the shrimp survey and CPUE observations.

This procedure has been taken into use in the 2014 assessment, although we expect that the increased uncertainty of the stock status at the end of the current year will increase the risk estimates associated with future catches.

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