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Applying a stochastic surplus production model (SPiCT) to the West Greenland Stock of *Pandalus montagui*

by

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Summary

A stochastic surplus production model (SPiCT) was applied to the West Greenland stock of *Pandalus montagui*. Input data composed of survey biomass, catch and commercial CPUE index during the period 2001 to 2017. The model was unstable for removing last year of data. The output indicated that relative biomasse and fishing mortality were within safe biological limits but also that the uncertainties of the estimates were very broad. The results should only be considered as indicative and as a first attempt to make an analytical assessment of the *P. montagui* stock, which may be improved in the future.

Introduction

The SPiCT model is a stochastic surplus production model in continuous time (Pedersen & Berg, 2016). No analytical assessment has so far been performed of the West Greenland *Pandalus montagui* stock. The model was applied to assess whether the model may be a candidate for future assessment. The model assumptions are:

1. The intrinsic growth rate represents a combination of natural mortality, growth, and recruitment.
2. The biomass refers to the exploitable part of the stock.
3. The stock is closed to migration
4. Age and size-distribution are stable in time.
5. Constant catchability of the gear used to gather information for the biomass index.

Material and Methods

The input data was chosen to cover the period from 2001 to 2017. Catch data are derive from the Greenlandic Fishery and Licence Control (GFLK). The catch in 2008 and 2009 of 89 and 53 t were considered extreme low and was omitted from the analyses. The catch in 2017 was set to the mean of the catch in 2015-2016. *P. montagui* is mainly caught as by-catch in the fishery for *P. borealis,* although some vessels appear occasionally to target *P. montagui.* Survey index of total biomass (not the exploitable part) excluding the biomass below 150 m derived from the Greenland stratified random bottom survey (Burmeister and Rigét, 2017). The survey is principally designed according to the distribution of *P. borealis* and not *P. montagui,* the latter having its main distribution in shallower waters. However, the reason for excluding the biomass of *P montagui* situated in shallow water and thereby an unknown part of the biomass, was to reflect the commercial fishing depths for *P. borealis.*

The CPUE time-series derived from the logbooks of five offshore vessels, which are known to regularly tagging *P. montagui* and where the records is assumed to be most reliable reporters of *P. montagui.* A standardised CPUE index was estimated by GLM including vessel, month, area and year as factors. Input data are shown in Table 1 and Fig.1.

Results and Discussion

Preliminary run of the SPiCT model would not converge, probably because of the relative short time-series. Fixing of the parameter n = 2 (symmetric Schaefer production curve) resulted in a converged model fit. Several of the estimated model parameters have extreme broad confidence limits, which might be caused by occurrence of years with extreme survey biomass or CPUE index values. The correlations were high (above 0.89/ below -0.89) in-between the log value of carrying capacity (K) and the catchabilities (q's) showing that these parameters are not well separated. Also the correlation between B_{MSY} and F_{MSY} was high (-0.90). The result described below should be considered only as indicative.

Model residuals and diagnostic are shown in Fig. 2. The One Step Ahead (OSA) residuals were not significant different from zero for any of the data series and therefore not biased (above figure row). Testing of multiple lags (here 4) show no significant autocorrelation of the residuals (ACF). Also in case of individual lags of the survey biomass index. The residuals were not significantly different from being normal distributed in any case.

The correlations between model parameters were very high (above 0.96/below -0.96) between the log value of maximum sustainable yield (m), carrying capacity (K) and the catchabilities (q) showing that these parameters are not well separated (Table 2). Furthermore, the correlation between B_{MSY} and F_{MSY} was also high (-0.90). The result described below should be considered only as indicative.

Fig. 3 show the relative fishing mortality (F_t/F_{MSY}) and the relative biomass (B_t/B_{MSY}) derived from the SPiCT model. F_t/F_{MSY} has been well below 1 during the whole period. However, the 95% confidence interval of F_t/F_{MSY} is extreme large as also indicated by the blue color in the figure. B_t/B_{MSY} has since 2007/2008 been above 1.

Retrospective analyses by shortened the data series by 1 to 3 last observations (Fig. 4) showed that the model output was highly dependent of last year data point indicating that robustness of the model was low.

Table 3 show the stochastic reference points from the SPiCT model. B_{MSY} is estimated to10,831 t, B_{2017}/B_{MSY} to 1.37 and F_{2017}/F_{MSY} to 0.65. However, the confidence limits were very large and included estimate far below 1 in case of B_{2017}/B_{MSY} and far above 1 in case of F_{2017}/F_{MSY}. The predicted catch in 2018 at $F = F_{2017}$ amount to 2421 t.

No forecast scenarios are given for West Greenland *Pandalus montagui* stock.

Conclusion

The SPiCT model indicated that F_{2017}/F_{MSY} is above 1 and B/ B_{MSY} close to 1. However, the model were unstable and the confidence limits of the reference points too large. The results are therefore as best only indicative.

References

PEDERSEN, M.W., BERG, C.W. 2017. A stochastic surplus production model in continuous time. Fish & Fisheries, 18(2), pp 226-243.

Table 1. *Pandalus montagui* in West Greenland. Input data to a surplus production model.

Year	Catch	Survey index	CPUE index
2001	720	2471	0.8906
2002	184	6562	0.6507
2003	793	1153	0.7599
2004	789	383	1.5926
2005	504	332	1.5059
2006	1419	5894	1.4411
2007	1966	222	2.5015
2008	-	403	0.3821
2009	-	717	0.7250
2010	1168	773	2.2729
2011	2324	172	5.8773
2012	3121	1446	1.3133
2013	4944	1291	1.6528
2014	1357	413	1.2642
2015	2027	1637	1.7784
2016	3176	2109	2.8211
2017	2602[1]	3633	1.0000

[1] Mean of the two years before

Table 2. Correlation matrix for the estimated SPiCT model parameters

	logm	logK	logq	logq	logn
logm	1.0000000000	0.8950214551	-0.894645665	-0.905121163	1.533921e-04
logK	0.8950214551	1.0000000000	-0.909417213	-0.920065677	-4.883745e-04
logq	-0.8946456649	-0.9094172130	1.000000000	0.966061720	1.188790e-04
logq	-0.9051211626	-0.9200656772	0.966061720	1.000000000	1.202710e-04
logn	0.0001533921	-0.0004883745	0.000118879	0.000120271	1.000000e+00
logsdb	0.0595081106	-0.1304312855	0.025100674	0.025394583	1.998422e-04
logsdf	-0.0711981651	-0.0849199773	-0.059552137	-0.060249438	1.892168e-05
logsdi	-0.0762620062	-0.1998720011	0.198273644	0.200595256	5.099788e-06
logsdi	0.0483744648	0.1551498381	-0.107068771	-0.108322438	3.977457e-06
logsdc	0.0153139944	-0.0534786633	-0.011522323	-0.011657238	-5.666002e-05

	logsdb	logsdf	logsdi	logsdi	logsdc
logm	0.0595081106	-7.119817e-02	-7.626201e-02	4.837446e-02	1.531399e-02
logK	-0.1304312855	-8.491998e-02	-1.998720e-01	1.551498e-01	-5.347866e-02
logq	0.0251006738	-5.955214e-02	1.982736e-01	-1.070688e-01	-1.152232e-02
logq	0.0253945827	-6.024944e-02	2.005953e-01	-1.083224e-01	-1.165724e-02
logn	0.0001998422	1.892168e-05	5.099788e-06	3.977457e-06	-5.666002e-05
logsdb	1.0000000000	1.555695e-01	7.458933e-02	1.916033e-02	9.515186e-02
logsdf	0.1555695144	1.000000e+00	-1.037224e-01	3.097886e-02	3.596926e-02
logsdi	0.0745893303	-1.037224e-01	1.000000e+00	-1.302285e-01	1.004638e-02
logsdi	0.0191603278	3.097886e-02	-1.302285e-01	1.000000e+00	-3.044729e-02
logsdc	0.0951518613	3.596926e-02	1.004638e-02	-3.044729e-02	1.000000e+00

Table 3. Results from the SPiCT model including parameter estimates, reference points and predictions

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Convergence: 0  MSG: relative convergence (4)
Objective function at optimum: 73.95038
Euler time step (years):  1/16 or 0.0625
Nobs C: 15,  Nobs I1: 17,  Nobs I2: 17

Priors
     logn  ~  dnorm[log(2), 0.001^2] (fixed)
 logalpha  ~  dnorm[log(1), 2^2]
  logbeta  ~  dnorm[log(1), 2^2]

Model parameter estimates w 95% CI
            estimate        cilow        ciupp    log.est
 alpha1 9.519258e+00    2.1657899 4.183983e+01  2.2533170
 alpha2 6.663104e+00    1.4877908 2.984086e+01  1.8965855
 beta   3.732490e+00    0.4958405 2.809670e+01  1.3170757
 r      5.079062e-01    0.1455816 1.771987e+00 -0.6774585
 rc     5.079062e-01    0.1455820 1.771983e+00 -0.6774585
 rold   5.079062e-01    0.1455819 1.771984e+00 -0.6774584
 m      2.818932e+03  820.3476047 9.686598e+03  7.9441134
 K      2.220041e+04 2395.4745281 2.057456e+05 10.0078662
 q1     1.049825e-01    0.0056713 1.943360e+00 -2.2539620
 q2     1.645000e-04    0.0000092 2.944400e-03 -8.7124639
 n      2.000000e+00    1.9960837 2.003924e+00  0.6931471
 sdb    1.369895e-01    0.0317626 5.908237e-01 -1.9878510
 sdf    1.364864e-01    0.0186053 1.001247e+00 -1.9915306
 sdi1   1.304039e+00    0.9017195 1.885860e+00  0.2654660
 sdi2   9.127753e-01    0.6347919 1.312491e+00 -0.0912655
 sdc    5.094340e-01    0.3410502 7.609526e-01 -0.6744549

Deterministic reference points (Drp)
           estimate       cilow        ciupp   log.est
 Bmsyd 1.110021e+04 1197.737531 1.028728e+05  9.314719
 Fmsyd 2.539531e-01    0.072791 8.859914e-01 -1.370606
 MSYd  2.818932e+03  820.347605 9.686598e+03  7.944113
Stochastic reference points (Srp)
           estimate        cilow        ciupp   log.est rel.diff.Drp
 Bmsys 1.083115e+04 1179.5347908 9.945774e+04  9.290182  -0.02484080
 Fmsys 2.493608e-01    0.0707969 8.782992e-01 -1.388854  -0.01841631
 MSYs  2.699629e+03  809.9444560 8.998147e+03  7.900870  -0.04419219

States w 95% CI (inp$msytype: s)
                 estimate       cilow        ciupp    log.est
 B_2017.00      1.488198e+04 750.5188400 2.950936e+05  9.6079063
 F_2017.00      1.630996e-01   0.0085051 3.127699e+00 -1.8133940
 B_2017.00/Bmsy 1.373998e+00   0.4744352 3.979194e+00  0.3177246
 F_2017.00/Fmsy 6.540708e-01   0.0760496 5.625392e+00 -0.4245397

Predictions w 95% CI (inp$msytype: s)
               prediction        cilow        ciupp    log.est
 B_2018.00      1.484014e+04  726.3628773 3.031952e+05  9.6050909
 F_2018.00      1.634624e-01    0.0084189 3.173792e+00 -1.8111725
 B_2018.00/Bmsy 1.370135e+00    0.4704209 3.990617e+00  0.3149092
 F_2018.00/Fmsy 6.555254e-01    0.0751142 5.720801e+00 -0.4223182
 Catch_2018.00  2.421213e+03 1353.0767518 4.332551e+03  7.7920241
 E(B_inf)       1.408857e+04           NA           NA  9.5531192
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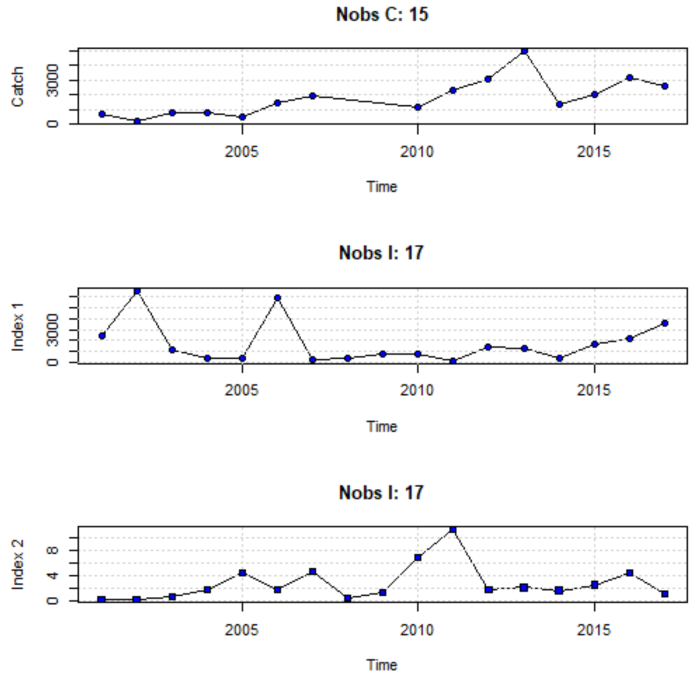

Fig. 1. Input data for the SPiCT models. Top: Catch, Mittel: Survey index, Bottom: CPUE index.

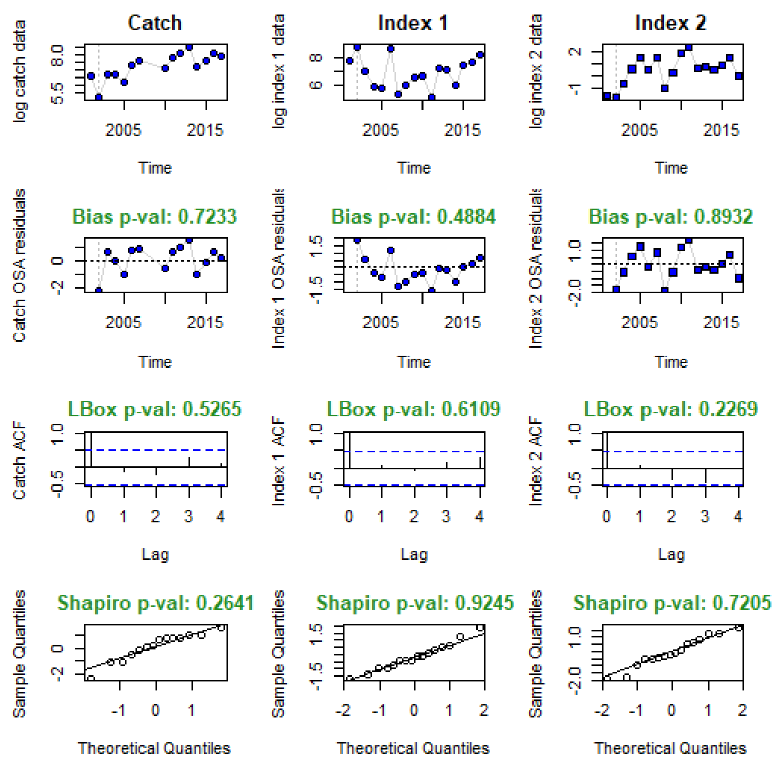

Fig. 2. Diagnostics. First column show log of the input data series; catch, survey index and CPUE. Second column "one-step ahead" (OSA) residuals and a test for bias, Third column show the autocorrelation of the residuals including Ljung-Box test of multiple lags and tests for the individual lags. Fourth column test for normality of the residuals.

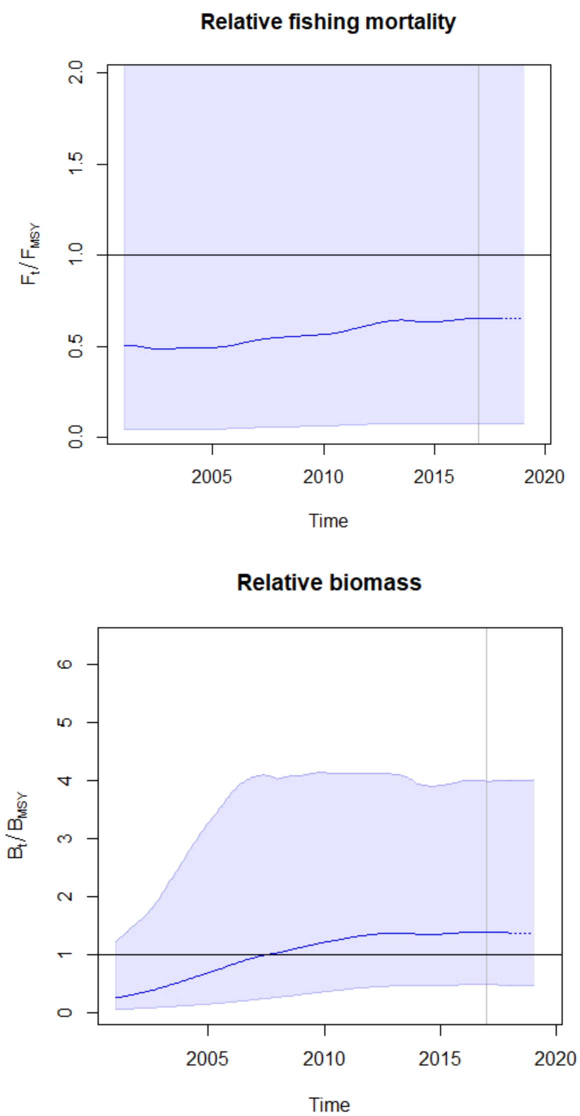

Fig. 3. Plot of the estimated relative fishing mortality (F_t/F_{MSY}) and relative biomass (B_t/B_{MSY}) trough time.

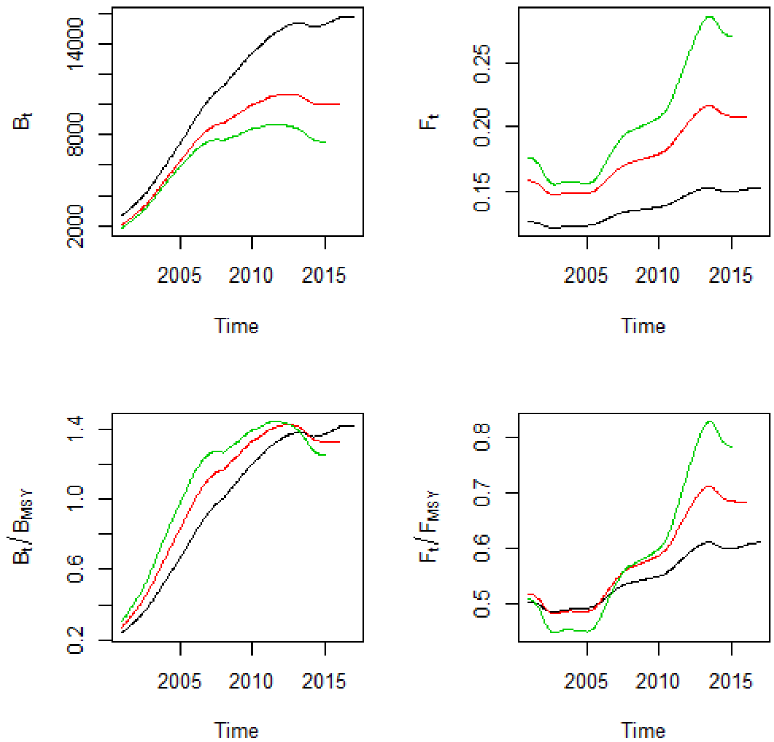

Fig. 4. Retrospective plots of fishing mortality and fishable biomass with 4 scenarios where the time-series of catch, survey and CPUE are shortened by the 1 to 4 last observations of the West Greenland stock of *P. montagui*.