A first approach to stock assessment of pollack in ICES subarea 8 and division 9a using SPiCT

Paz Sampedro
paz.sampedro@ieo.es , Centro Oceanográfico de A Coruña, Paseo Marítimo Alcalde Francisco Vázquez, 10, 15001 A Coruña, Spain

Abstract

A SPiCT model has been fitted for Pollack stock in ICES subarea 8 and division 9a (pol.27.8.9a). Different scenarios were tested based on abundance indices series selected, time period considered, and the model's options of fixing model parameters and the definition of priors. The implementation showed that the best model was for scenario using the landing series 1986-2018 and the abundance index FR-GNS>902s 2005-2018. Although the uncertainty around the parameters and reference points is high, the estimates of K, r, F and B are realistic indicating that SPiCT could be a good option for assessing this stock.

Introduction

Pollack is a bentho-pelagic species distributed in the Northeast Atlantic with a main distribution from the Portuguese continental coast northwards around the British Isles, into the Skagerrak and along the Norwegian coast where it is fairly common up to the Lofoten Islands. ICES has provided a precautionary advice on pollack in subarea 8 and division 9a based on stock assessment conducted in 2019. In this work, a surplus production model in continuous time (SPiCT) was applied to pollack stock.

Material and Methods

Data

Catch data come from different sources (International data-bases, ICES database and ROMELIGO project) and have been collected for the stock assessment of pol.27.8.9a (Table 1). Three time series of commercial index were compiled. The series "FR-GNS>90-2s" (French Gillnets with mesh size > 90 mm, operating in North Bay of Biscay during the second semester) was provided by ROMELIGO Project for the years 2005-2018 to the WGBIE2019, and the series "GAL-GN-60-79_8c" (Galician Gillnets with mesh size 60-79 operating in 8c) and "GAL-GN-60-79_9ª" (Galician Gillnets with mesh size 60-79 operating in 9a) are available for the period 2000-2016 in published information (Alonso-Fernández et al., 2019).

Model Description

The SPiCT model (Surplus Production model in Continuous Time) is based on the generalized surplus production model, known as the Pella-Tomlinson model, where the shape of the production curve may deviate from the symmetric form. A detailed description of the SPiCT model and all the options available can be found in Pedersen and Berg (2017). The model has a general state-space form that can contain process and observation-error as well as state-space models that assume error-free catches. SPiCT assumes that catches and CPUE indices contain observation error, and the process error in the surplus production function is also estimated. SPiCT has the option of using some weak priors on the production curve shape parameter and

the ratios of observation to process error or to perform a frequentist analysis without any priors. The analysis were performed using the R package spict *v.1.2.8* available at https://github.com/DTUAqua/spict

Table 1. Input data available for pollack to perform SPiCT. *Landings in 1999 are estimated

Year	Landings (tonnes)	FR-GNS>90-2s (kg/fishing sequence)	% Stock Landings	GAL-GN-60-79_8c (ind/haul)	GAL-GN60-79_9a (ind/haul)
1986	2806				
1987	2918				
1988	2582				
1989	1973				
1990	1900				
1991	2168				
1992	1958				
1993	1513				
1994	1955				
1995	1679				
1996	1354				
1997	1378				
1998	1165				
1999	1322				
2000	1479			1.98	0.89
2001	1746			0.95	0.55
2002	1972			0.95	0.41
2003	1663			2.18	1.09
2004	1726			1.36	0.55
2005	1986	115	5.3	2.32	1.02
2006	2126	66	2.5	1.36	1.36
2007	1847	129	6.7	0.55	0.48
2008	2313	129	6.2	0.89	0.55
2009	1812	124	6.2	0.89	0.27
2010	1682	108	5.5	1.23	1.09
2011	2032	197	7.7	0.55	0.00
2012	1520	174	10.7	0.55	0.00
2013	1811	157	8.9	1.43	0.82
2014	1959	150	9.1	1.09	0.55
2015	1610	144	10.4	0.82	0.14
2016	1661	121	9.0	0.61	1.64
2017	1481	122	9.2		
2018	1512	112	7.4		

Scenarios

Three different scenarios were fit:

Scenario 1. Including the 3 CPUE indices available (Figure 1).
Scenario 2. Only with the time series of FR.GN.90.2s index.
Scenario 3. Data restricted to the 2005-2018 period.

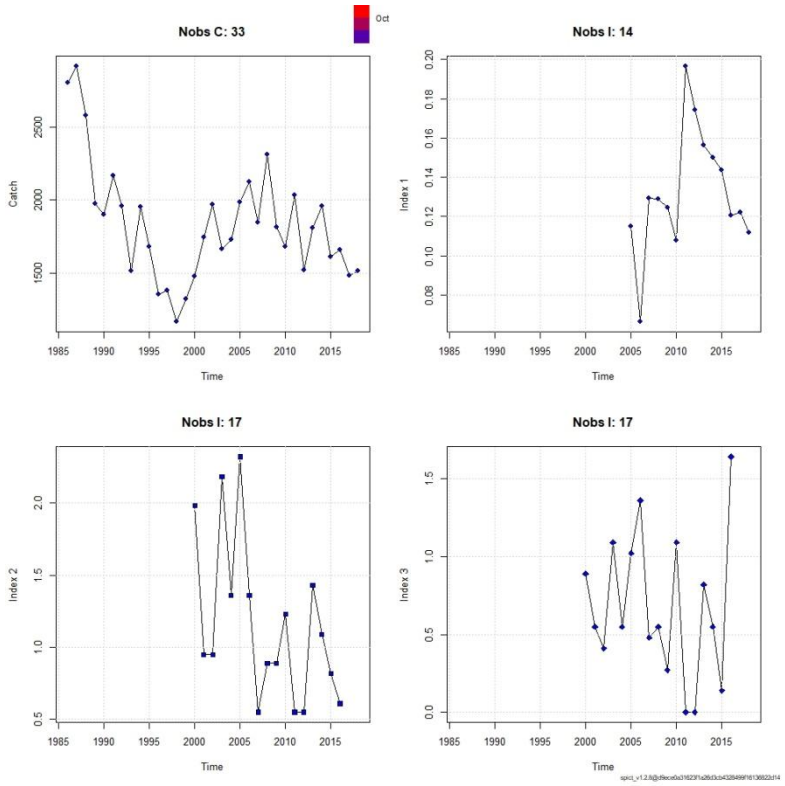


Figure 1. Data used for the SPiCT model.

Results

Scenario 1. The model didn't converge under this scenario. Different priors and options were tried, but it was no possible to get the convergence. This scenario was performed as a trial, as we knew that the two "GAL-GN_60_79" were abundance indices (ind/haul) and SPICT requires biomass indices. The two time series were discarded to be used as indices:

```
Convergence: 1  MSG: false convergence (8)
WARNING: Model did not obtain proper convergence! Estimates and uncertainties are most likely invalid and cannot be trusted.
Gradient at current parameter vector
       logm        logK        logq        logq
  340200916 -15405231125  -7877841761  -6975665140
       logq      logsdb      logsdf      logsdi
 -352240442   455548313 -1356673996   1868871383
     logsdi      logsdi      logsdc
-2750079384   -494792173   273986241

Objective function: 45.393069
Euler time step (years):  1/16 or 0.0625
Nobs C: 33,  Nobs I1: 14,  Nobs I2: 17,  Nobs I3: 17
Priors
 logbkfrac ~ dnorm[log(0.4), 0.5^2]
    logn ~ dnorm[log(2), 2^2]
 logalpha ~ dnorm[log(1), 2^2]
 logbeta ~ dnorm[log(1), 2^2]
Fixed parameters
  fixed.value
n         2
Model parameter estimates w 95% CI
         estimate       cilow       ciupp     log.est
alpha1 4.547214e+00         NaN         NaN   1.5145147
alpha2 8.576793e+00   6.8309445   10.7688448   2.1490601
alpha3 3.816789e+01         NaN         NaN   3.6419946
beta   9.384499e-01         NaN         NaN  -0.0635258
r      4.428774e-01         NaN         NaN  -0.8144623
```

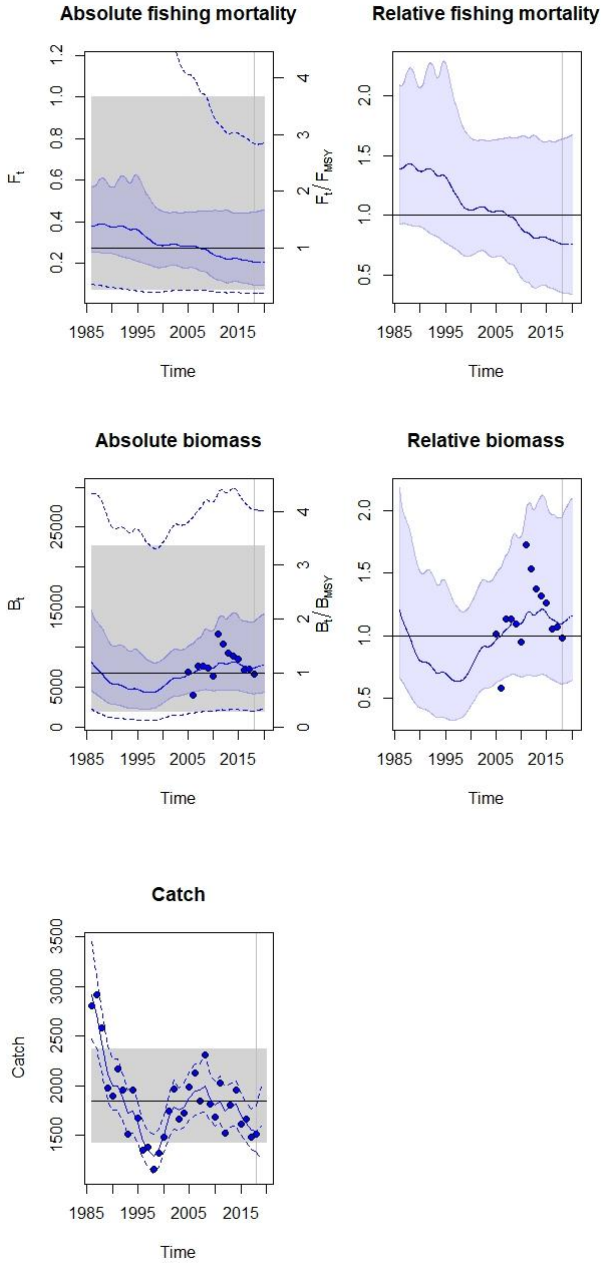
```
rc     4.428774e-01         NaN         NaN  -0.8144623
rold   4.428774e-01         NaN         NaN  -0.8144623
m      2.022001e+03 2000.2657301 2043.9723119   7.6118429
K      1.826240e+04         NaN         NaN   9.8125995
q1     1.130000e-05         NaN         NaN -11.3880312
q2     9.190000e-05         NaN         NaN  -9.2953452
q3     2.400000e-05         NaN         NaN -10.6364315
sdb    5.480930e-02         NaN         NaN  -2.9038957
sdf    9.842900e-02         NaN         NaN  -2.3184194
sdi1   2.492296e-01         NaN         NaN  -1.3893809
sdi2   4.700879e-01    0.4022154    0.5494137  -0.7548356
sdi3   2.091955e+00    2.0532006    2.1314403   0.7380989
sdc    9.237070e-02         NaN         NaN  -2.3819453
Deterministic reference points (Drp)
         estimate    cilow    ciupp   log.est
Bmsyd  9131.1990234      NaN      NaN 9.119452
Fmsyd    0.2214387      NaN      NaN -1.507609
MSYd  2022.0009319 2000.266 2043.972  7.611843
Stochastic reference points (Srp)
         estimate    cilow    ciupp   log.est
Bmsys 9092.0388256      NaN      NaN  9.115154
Fmsys    0.2206993      NaN      NaN -1.510954
MSYs  2006.5779889 1985.395 2027.987  7.604186
      rel.diff.Drp
Bmsys -0.004307087
Fmsys -0.003350305
MSYs  -0.007686192
States w 95% CI (inp$msytype: s)
                estimate      cilow       ciupp
B_2018.00     1.159331e+04 930.7486705 1.444052e+05
F_2018.00     1.321026e-01   0.0087066 2.004345e+00
B_2018.00/Bmsy 1.275106e+00   0.1018978 1.595613e+01
F_2018.00/Fmsy 5.985635e-01   0.0392758 9.122122e+00

               log.est
B_2018.00      9.3581838
F_2018.00     -2.0241767
B_2018.00/Bmsy  0.2430293
F_2018.00/Fmsy -0.5132227

Predictions w 95% CI (inp$msytype: s)
              prediction       cilow       ciupp
B_2019.00     1.186452e+04 1276.6749328 1.102605e+05
F_2019.00     1.309006e-01   0.0097542 1.756671e+00
B_2019.00/Bmsy 1.304935e+00   0.1397139 1.218816e+01
F_2019.00/Fmsy 5.931175e-01   0.0439974 7.995669e+00
Catch_2019.00  1.568420e+03  914.3729741 2.690303e+03
E(B_inf)      1.272223e+04          NA          NA
               log.est
B_2019.00      9.3813077
F_2019.00     -2.0333168
B_2019.00/Bmsy  0.2661532
F_2019.00/Fmsy -0.5223628
Catch_2019.00   7.3578238
E(B_inf)        9.4511060
```

Scenario 2. The model converged and the main estimates were considered realistic values:

```
Convergence: 0  MSG: relative convergence (4)
Objective function at optimum: -3.2835623
Euler time step (years):  1/16 or 0.0625
Nobs C: 33,  Nobs I1: 14

Priors
 logbkfrac  ~  dnorm[log(0.4), 0.5^2]
     logn  ~  dnorm[log(2), 2^2]
  logalpha  ~  dnorm[log(1), 2^2]
   logbeta  ~  dnorm[log(1), 2^2]

Fixed parameters
  fixed.value
n         2

Model parameter estimates w 95% CI
         estimate       cilow       ciupp     log.est
alpha  2.558159e+00    0.8276700 7.906748e+00   0.9392879
beta   1.360615e+00    0.3235980 5.720907e+00   0.3079371
r      5.504379e-01    0.1509260 2.007486e+00  -0.5970412
rc     5.504379e-01    0.1509260 2.007486e+00  -0.5970412
rold   5.504379e-01    0.1509260 2.007486e+00  -0.5970412
m      1.873679e+03 1470.1086459 2.388036e+03   7.5356590
K      1.361591e+04 4044.9930110 4.583274e+04   9.5189946
q      1.690000e-05    0.0000045 6.320000e-05 -10.9881842
sdb    8.791260e-02    0.0343829 2.247813e-01  -2.4314117
sdf    7.004160e-02    0.0201327 2.436743e-01  -2.6586656
sdi    2.248945e-01    0.1386090 3.648936e-01  -1.4921238
sdc    9.529970e-02    0.0623478 1.456672e-01  -2.3507285

Deterministic reference points (Drp)
        estimate      cilow       ciupp   log.est
Bmsyd 6807.9571473 2022.496506 22916.371125  8.825847
Fmsyd    0.2752189    0.075463    1.003743 -1.290188
MSYd  1873.6787699 1470.108646  2388.035839  7.535659
Stochastic reference points (Srp)
       estimate       cilow       ciupp   log.est
Bmsys 6743.692351 2006.6757075 22663.047328  8.816363
Fmsys    0.273336    0.0745747     1.001848 -1.297054
MSYs  1843.172759 1435.1973177  2367.121075  7.519244
     rel.diff.Drp
Bmsys -0.009529616
Fmsys -0.006888749
MSYs  -0.016550815

States w 95% CI (inp$msytype: s)
                  estimate       cilow       ciupp
B_2018.00       7389.4328014 2010.5302360 2.715886e+04
F_2018.00          0.2076003    0.0554810 7.768044e-01
B_2018.00/Bmsy     1.0957547    0.6172542 1.945193e+00
F_2018.00/Fmsy     0.7595059    0.3524866 1.636514e+00
              log.est
B_2018.00      8.9078063
F_2018.00     -1.5721407
B_2018.00/Bmsy  0.0914434
F_2018.00/Fmsy -0.2750871

Predictions w 95% CI (inp$msytype: s)
             prediction       cilow       ciupp
B_2019.00     7603.7905849 2133.2491224 2.710308e+04
F_2019.00        0.2064361    0.0551233 7.731012e-01
B_2019.00/Bmsy   1.1275411    0.6255371 2.032412e+00
F_2019.00/Fmsy   0.7552468    0.3454987 1.650940e+00
Catch_2019.00 1591.9568594 1274.8107811 1.988002e+03
E(B_inf)      8281.7260674          NA          NA
              log.est
B_2019.00      8.9364022
F_2019.00     -1.5777642
B_2019.00/Bmsy  0.1200393
```

F_2019.00/Fmsy -0.2807107
Catch_2019.00 7.3727193
E(B_inf) 9.0218067

The uncertainty around the reference points is high (Figure 4, grey boxes). The relative values of F and B have narrower confidence intervals. Sensitivity analysis of input values a few trials didn't converge. The overall trend of F/F_{MSY} was decrease since 1986, and the estimate below 1 since 2008. Also, the B/BMSY is above 1 since 2007.



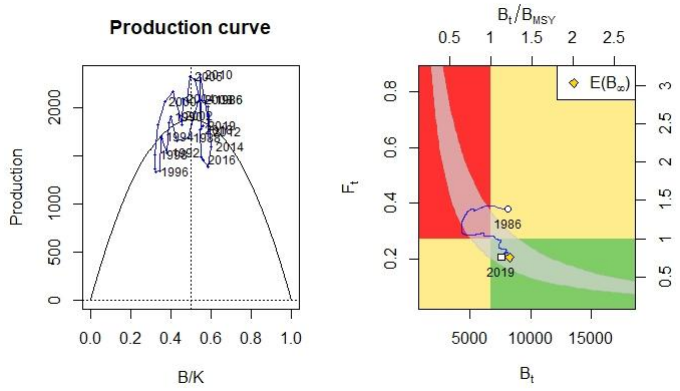


Figure 2. Scenario 2. Plots of results.

Scenario 3. The trial to fit the model to a shorten series, for the period of years (2005-2018) with data for landings and the abundance index. The convergence was not possible. Probably, the absence of contrast in the landing data prevented the model to get a solution.

```
Convergence: 1  MSG: false convergence (8)
WARNING: Model did not obtain proper convergence! Estimates and uncertainties are most likely invalid and cannot be trusted.

Gradient at current parameter vector
     logm      logK      logq     logsdb     logsdf
 469505.63 -546136.87 -539987.19    8135.98 -177966.33
    logsdi     logsdc
 192687.77  -22673.93

Objective function: -1.4832589
Euler time step (years):  1/16 or 0.0625
Nobs C: 14,  Nobs I1: 14

Priors
 logbkfrac  ~  dnorm[log(0.4), 0.5^2]
     logn  ~  dnorm[log(1.478), 0.6^2]
  logalpha  ~  dnorm[log(1), 2^2]
   logbeta  ~  dnorm[log(1), 2^2]

Fixed parameters
  fixed.value
n         2

Model parameter estimates w 95% CI
         estimate       cilow       ciupp    log.est
alpha    1.2489836   0.7481107   2.0851995  0.2223301
beta     0.6474307   0.4527695   0.9257833 -0.4347436
r       39.1820659         NaN         NaN  3.6682191
rc      39.1820659         NaN         NaN  3.6682191
rold    39.1820659         NaN         NaN  3.6682191
m     2170.6793407 2067.5970780 2278.9008797  7.6827955
K      221.5992743         NaN         NaN  5.4008707
q        0.0009032         NaN         NaN -7.0095640
sdb      0.1737624   0.1703520   0.1772411 -1.7500665
sdf      0.1460958   0.1005347   0.2123045 -1.9234928
sdi      0.2170264   0.1310074   0.3595250 -1.5277364
sdc      0.0945869   0.0930420   0.0961575 -2.3582364

Deterministic reference points (Drp)
       estimate    cilow    ciupp  log.est
```

```
 Bmsyd  110.79964      NaN      NaN 4.707724
 Fmsyd   19.59103      NaN      NaN 2.975072
 MSYd  2170.67934 2067.597 2278.901 7.682796
Stochastic reference points (Srp)
       estimate    cilow    ciupp  log.est  rel.diff.Drp
 Bmsys  110.79909      NaN      NaN 4.707719 -4.980652e-06
 Fmsys   19.59285      NaN      NaN 2.975164  9.258300e-05
 MSYs  2170.86952 2067.755 2279.126 7.682883  8.760418e-05

States w 95% CI (inp$msytype: s)
              estimate     cilow     ciupp    log.est
 B_2018.00     161.2147428       NaN       NaN  5.0827373
 F_2018.00       9.1048022 7.7495066 10.6971226  2.2088020
 B_2018.00/Bmsy   1.4550187 1.4146532  1.4965360  0.3750188
 F_2018.00/Fmsy   0.4647003 0.3751508  0.5756255 -0.7663626

Predictions w 95% CI (inp$msytype: s)
             prediction       cilow       ciupp
 B_2019.00      169.5732401        NaN        NaN
 F_2019.00       8.9882152    7.1793196   11.2528788
 B_2019.00/Bmsy    1.5304570    1.2689356    1.8458768
 F_2019.00/Fmsy    0.4587498    0.3433665    0.6129061
 Catch_2019.00  1533.8244179 1217.1789676 1932.8442304
 E(B_inf)       170.5992137         NA         NA
              log.est
 B_2019.00      5.1332849
 F_2019.00      2.1959143
 B_2019.00/Bmsy  0.4255664
 F_2019.00/Fmsy -0.7792502
 Catch_2019.00   7.3355195
 E(B_inf)       5.1393170
```

Conclusion

Although the scenario 2 provided acceptable results, the model relies on the information from only one index and very short period of the years. Besides, the decision to adopt the SPiCT as model for pollack 89a assessment needed the compromise of France to send every year the value of FR-GN-902s. As the available time series for FR-GN-902s stopped with the end of the ROMELIGO Project.

References

Alonso-Fernández, A., Otero, J., Bañón, R., Campelos, J. M., Quintero, F., Ribó, J., et al. 2019. Inferring abundance trends of key species from a highly developed small-scale fishery off NE Atlantic. *Fisheries Research*, 209: 101–116. doi: 10.1016/j.fishres.2018.09.011.

Pedersen, M.W. and C. W. Berg. 2017. A stochastic surplus production model in continuous time. *Fish and Fisheries,* 18: 226-243. url:https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12174, doi:10.1111/faf.12174.