**DDwSE3\_jags**

**Purpose**  This is the model for both Brown Bank North and Georges Bank “a”. This isn’t an R script but is a model written in BUGS/JAGS language

**Version Control**  This builds on DDwSE3 which is the winBUGS version of this JAGS code. This basically moved from winBUGS into JAGS, but I have added some output and commenting to the function…

**Required packages** R2jags (the locally derived functions have their own package needs as well)

**Preamble**

This help file has two function; a: it explains how the model is conceptually put together, this is done in an effort to help walk a new user through the model is as non-technical/jargony fashion as possible, it’s a reasonably complex model so it’s not light lifting no matter what, and b: this breaks down the BUGS/JAGS code used for the offshore model and walks through the script as best as possible. One deviation that was undertaken was to start with a description of the model itself before discussing the priors (in the script the priors come first then the model), simply because if you don’t understand the model you really won’t understand the priors. I don’t’ get into any discussion of Bayesian modelling, you’ll need to look elsewhere to understand that

**The model**

A slight aside to start; The model is run on what is known as a “survey year”. A survey year runs from the end of the survey (Generally August on GBa and May on BBn) to the following years survey, this obviously differs from a calendar year which is how the TAC for the fishery is set thus when you run this model you need to be wary that you have this complecation sorted out in your head. The help scripts for the associated functions should help you here and everything is set up in these scripts to account for this quirk.

The heart of this model is a Delay-difference model. The underlying model accounts for natural mortality, physical growth of the scallops over the course of a year, the catch of the scallops by the fishery, and the addition to the population from smaller scallops not yet “incorporated” into the fishery (recruit scallops). This leads to the frightening looking equation…

(1)

While it looks scary it is nothing but a simple balance equation of removals and additions to the population, let’s define some terms

* Biomass (usually in tonnes or kT), this is the biomass at the time of the

survey. This is

* Natural mortality of fully recruited scallop. This is considered the

mortality for the current survey year (*t*), it is applied to the Biomass remaining after accounting for catch in the current “survey year” (*t*) and growth of that biomass over the course of the year.

* Annual growth rate of scallop found in survey from previous year (*t-1*)

The model enables growth to slow as average weight of the population increases (large individuals grow more slowly). Growth model details are outlined in detail below.

* Biomass (usually in tonnes or kT), estimate from previous survey (*t-1*)
* Fisheries catch (usually in tonnes or kT) during the “survey year”.
* Natural mortality of recruit scallops. This is considered the

mortality for the current survey year (*t*), it is applied to the Biomass of recruits from last “survey year” (*t*) and growth of that biomass over the course of the year. Note that catch for the recruits is assumed to be 0.

* Annual growth rate of recruit scallop found in survey from previous year

(*t-1*). Growth model details are outlined in detail below.

* Recruit Biomass (usually in tonnes or kT), this is the biomass at the time

of the previous survey (*t-1*)

*Removal terms*

In the model there are two avenues that result in a decline in the number of scallop. The easiest to deal with is the catch, which is simply the catch in tonnes from the end of the previous survey (*t-1*) to the end of the current survey (*t*). For GBa this is typically removals from September – August, for BBn this is typically removals from June-May.

The second removal term is the natural mortality. The natural mortality is calculated differently for both fully-recruit and recruit scallops. There are several pieces of information that the mortality terms are based on , the survey biomass, the CPUE (though this is down-weighted and I believe should be removed from the model in the next framework), and the clapper index. These 3 factors combine to give the mortality for fully recruited scallop. For the recruits the survey biomass and clapper index are the primary drivers of this, but of course it is a big complex model so the fully recruited terms will also have some impact on the recruit mortality estimates.

*Growth terms*

Growth in terms of biomass also happens via two avenues. I’ll start with the second and it leads more naturally to the first. We assume that all scallops in the recruit size class last year (*t-1*) grow and become part of the fully recruited size class this year. The recruit part of the equation is everything after the

The process model is

In terms of code this breaks down into these lines in the model script

Pmed[t] <- log(max(exp(-m[t]) \* g[t-1] \* (P[t-1] - C[t] / K) + exp(-mR[t])\*gR[t-1] \* r[t-1], 0.001))

# Now incorporate the process noise for our estimates of P

P[t] ~ dlnorm(Pmed[t], isigma2)

This is very much similar to Equation 1 above, but there are a couple of important difference to explain:

* Rescaled biomass, the biomass needs to be rescaled to help improve

the convergence of the Gibbs sampler (this is kinda the engine behind the JAGS/BUGS algorithims. The only reason we rescale if so the model converges more easily. Pt is simply rescaled by K to get back to fully recruited biomass.

* Rescaling constant, the biomass needs to be rescaled to help improve

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The model for the offshore survey.

*Clapper Model*

This model largely builds on the Dickie (1955) and Merrill and Posgay (1964) models which found (among many other things) that clappers once formed will last less than one year (somewhere between 50 and 231 days). Their solution to estimate natural mortality was a steady-state solution.

M is instantenous rate of natural mortality () , Z is the number of clappers, L is number of live individuals, and S is the time it takes for a clapper shell to separate (proportion of a year, 1 would mean it takes 1 year to separate the equation would simplify to meaning clappers were a direct estimate of mortality). Given the research above it appears clappers tend separate in under one year, so when we survey annually the clappers we see are some subset of the clappers that occur during the year. While more complex than if we could assume S = 1, we can at least think of S as a proportionality constant and don’t have to worry about accounting for clappers from previous years. This makes our calculations somewhat easier when we move from this steady-state solution to something more dynamic. The previous equation is actually the steady-state solution to this equation (I’m guessing if we sat down we could come up with other formulations that would give us this same result, but this is a reasonable model IMHO).

If we assume steady state thenand don’t vary over the course of a single year they can be considered constants in this equation, if you integrate it you’ll see you end up with the Dickie equation . Now one thing that messed with me for a bit, within this model time is multi-scaled, I think of *τ* is the time within a year (intra-annual) and is really looking at rates within a year, whereas *t* is interested in annual change (inter-annual). For example Z\_t term is the number of clappers in year t, whereas the terms inside the integral are saying these vary over the course of a year. So our intergration is attempting to look at changes over the course of a single year. This is nice as we can assume is a constant value for any one year and we can remove this from the integration, resulting in.

Now what to do with , this is the number of live indivduals during the year, we can assume this changes linearly over the course of the year. If we do this we can simply interpolate the number alive between last estimate and the current estimate at time *τ* (remember *τ* is on a within year scale, so *τ* is between 0 and 1, *τ* = 0 would represent 1 year ago, and *τ* = 1 would represent the most recent year). Doing so results in a simple weighted average/interpolation formula

Remember that the only reason we can do this within a year is that empirical evidence suggests *S < 1* (i.e. all clappers we see formed within the current year. Now we can pop this back into the main integral

Integration of this (good step by step walk through of this in the Appendix of Res Doc (2002/018 - Smith and Lundy 2002) with some re-arrangement to solve for results in (there are a couple of different ways this equation gets written, this is a nice way to see how the weighted average/interpolation across the separation time (S) remains in the model results).

Note that all of this ignores very real issued with clapper separation due to gear interactions and likely age effects in separation time, that could be address by a closer inspection of our survey results from seedboxes.

*Observation Model*

***Required Inputs***

***Priors***

1. logK.a
2. logK.b
3. r.a
4. r.b
5. m.a
6. m.b
7. mR.a
8. mR.b
9. S.a
10. S.b
11. q.a
12. q.b
13. qU.a
14. qU.b
15. sigma.a
16. sigma.b
17. ikappa.tau2.a
18. ikappa.tau2.b
19. ikappa.rho2.a
20. ikappa.rho2.b
21. I.precision.a
22. I.precision.b
23. IR.precision.a
24. IR.precision.b
25. U.precision.a
26. U.precision.b

***Data***

1. NY
2. C
3. g
4. gR
5. N
6. NR
7. clappers
8. clappersR
9. I
10. IR
11. U