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BUGS in fish stock assessment: challenges and potential remedies

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Contents

- Fish stock assessment: what and why?
- Typical model structure
- Some problems...
- and their partial solutions



Fish stock assessment: what and why?

- Idea is to support decision making
 - What happens to the fish population and to the profit of fishing industry under alternative decision options?
- This is a prediction task
 - How many fish there are at the moment?
 - Need methods for assessing the population size
 - How many fish there will be in next year?
 - Need for a population dynamics model and information about its parameters

$1 - C_{t-1, p}$

Trap

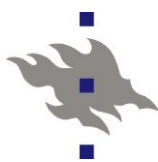
Trap

Trap

Trap

undefined real result
Pre: argument of Ln must not be negative

Math.Ln [0000018BH]		
.x	REAL	-0.7233781937837742
GraphStack.Node.Value [00001013H]		
.i	INTEGER	1
.j	INTEGER	1
.k	INTEGER	0
.node	GraphStack.Node	[010AB070H]
.op	INTEGER	14
.p	GraphNodes.Node	[010A8460H]
.top	INTEGER	0
.work	ARRAY 10 OF REAL	→ Elements ←
MonitorsSamples.StdMonitor.Update [00000265H]		
.blocks	POINTER	NIL
.i	INTEGER	0
.index	INTEGER	0
.monitor	MonitorsSamples.StdMonitor	[010C5600H]
.numBlocks	INTEGER	0
.value	REAL	2.758597844719908E-313
SamplesMonitors.Monitor.Update [000008F5H]		
.chain	INTEGER	0
.i	INTEGER	0
.monitor	SamplesMonitors.Monitor	[010246B0H]

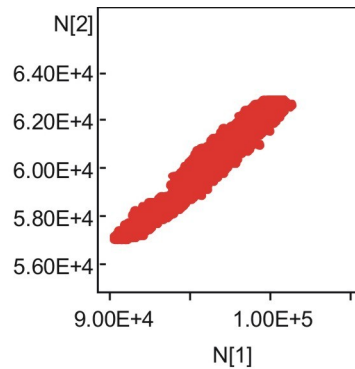
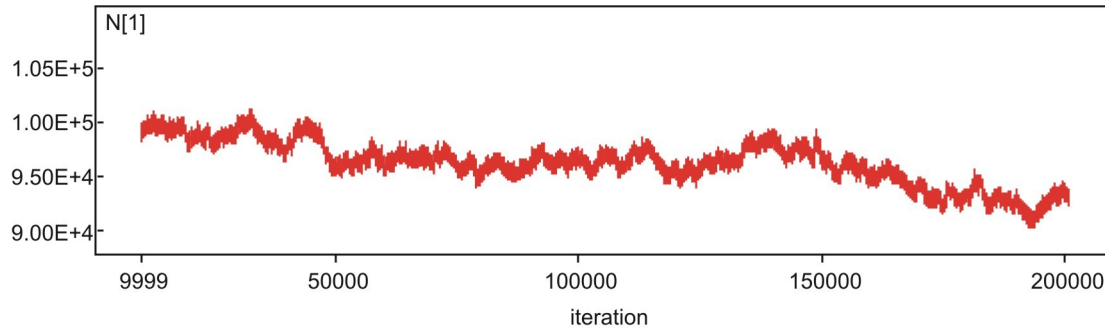
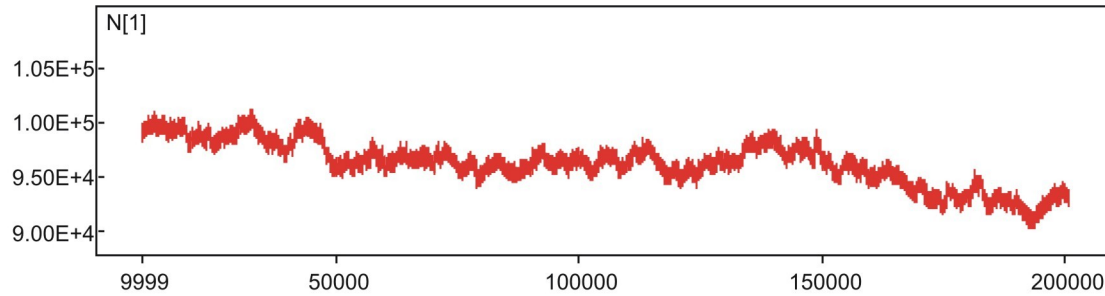


WinBUGS code

```
model{
N[1]<-round(exp(LN))
LN~dnorm(0,0.00001)
  for(y in 2:Y){
    N[y]~dbin(p,n[y-1])
  }
  for(y in 1:Y){
    C[y]~dbin(q,N[y])
    n[y]<-N[y]-C[y]
  }
p~dbeta(8,2)
q~dbeta(20,100)
}
```



After 200 000 iterations



Bugs manual says:
Find better parameterization!



Better parameterisation?

- Put prior on the ratio N_t/N_{t-1} :

$$N_t = \theta_t N_{t-1}$$

$$\theta_t | N_{t-1}, p \sim \text{Beta}(p(N_{t-1}-1), (1-p)(N_{t-1}-1))$$

- This preserves the mean and variance of the Binomial distribution, but the shape is slightly more skewed.

WinBUGS code:

```
N[y]<-round(theta[y]*n[y-1])
```

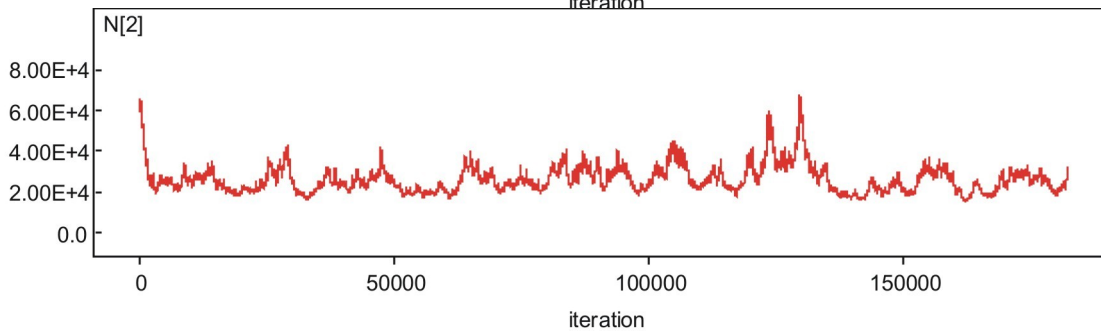
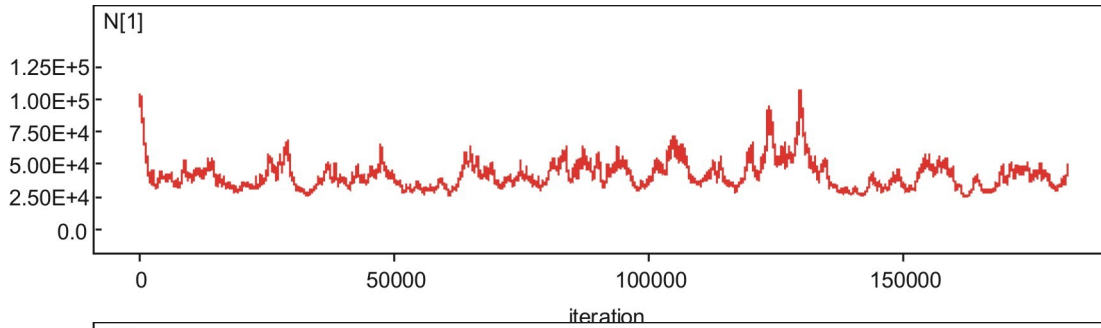
```
theta[y]~dbeta(a[y],b[y])
```

```
a[y]<-p*(n[y-1]-1)
```

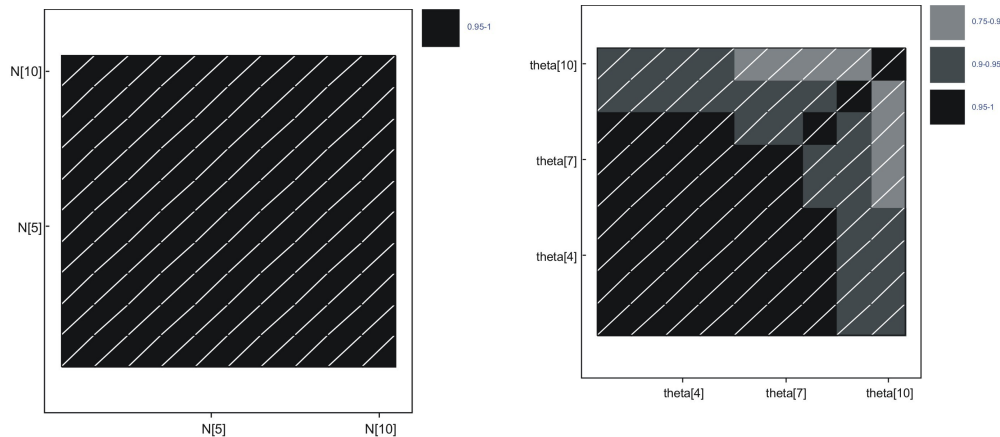
```
b[y]<-(1-p)*(n[y-1]-1)
```



After 200 000 iterations



This is better,
but not very
good





Even Better Parameterization?

- Maybe it does exist, any suggestions?
- Population sizes are correlated by the model definition. If they were not, we could not do much prediction!
- When reproduction dynamics is added to the model, even more correlation between parameters will be created
- Parameterization can help, but some correlation will probably remain between simulated variables
- Plan B: increase the speed of simulation and use lots of thinning

- Buy a faster computer: It still takes five days instead of a week

- Hard-
modul
- $$\alpha = \mu_1 - \frac{(\mu_A - \mu_1)(1 + e^{-\gamma(A-\delta)})}{e^{-\gamma(1-\delta)} - e^{-\gamma(A-\delta)}},$$
- $$\beta = \frac{(\mu_A - \mu_1)(1 + e^{-\gamma(A-\delta)})(1 + e^{-\gamma(1-\delta)})}{e^{-\gamma(1-\delta)} - e^{-\gamma(A-\delta)}}.$$

BenBUGS
says!



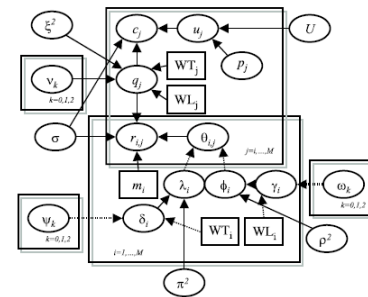
Alternative transition distributions?

- Clustering in survival: Beta-Binomial instead of Binomial
 - Beta-Bin can be also approximated well by using a single Beta distribution!
- Multiple states: Multinomial and Dirichlet-Multinomial distributions
 - Both can be approximated by a single Dirichlet
- Example:
 - Beta-Bin model: $x|N, p \sim \text{Bin}(N, p), p|a, b \sim \text{Beta}(a, b)$
 - can be approximated by
 - $x = \theta N, \theta | a^*, b^* \sim \text{Beta}(a^*, b^*)$
 - $a^* = e a / (a + b)$
 - $b^* = e b / (a + b)$
 - $e = [N (a + b + 1) / (N + a + b)] - 1$



Complex submodels

- For example, the catch (C) can be uncertain, but there is information about it obtained by taking samples from the catch
- The sampling needs to be modeled
 - This can be highly complex, and it may take a day to obtain the posterior distribution for the catch in one year
 - Given the complications of the simple population dynamics model, it is practically impossible to combine these models
- Sequential approach could help:
 - extract the marginal likelihood function of the catch from the complex catch-sampling model by using a flat prior
 - Find a simpler model and a “pseudo-observation” which will create approximately the same likelihood function for the catch and plug that model into the population dynamics





Summary

- Better parameterization of models makes it easier to utilize BUGS in fisheries modeling (Priors on proportions rather than on abundances)
- Use of OpenBUGS modules for deterministic calculations can significantly improve the speed
- Sequential analysis of submodels and the population dynamics model may be necessary
 - Downside is that this cuts the feedback from population dynamics model to the measurement model
- Dirichlet approximation of Multinomial-Dirichlet family might be more generally useful?
- Block updating of the matrix of abundances (or transition proportions) could be useful for the estimation of fishery models

Halt 126 : Not implemented yet