FISH 505 Assignment #8
DUE: March 20, 2009
Stock Assessment in Data Poor Situations

By definition, all stock assessments should be considered data limited as the information requirements to make objective decisions are often more costly than the revenue generated by the fishery itself. A common situation in fisheries stock assessment is dealing with cases in which historical information on removals and relative abundance index does not exists or is highly suspect. In such cases, we often omit the historical data and initialize the stock assessment model at some value less than the unfished stock size B_o. Furthermore, the time series data may also be information poor, where the data lack sufficient contrast to resolve confounding issues between productivity and the scale of the population (especially if we do not have information prior to exploitation). Such a situation exists for the Gulf of Mexico gag grouper stock assessments.

Using the time series data provided in the *GOM-gag.data* file and the life-history parameters listed in Table 1, fit an age-structured stock assessment model to these data (NB. the CPUE and mean age data are actually simulated data, so no you're not working on the really nasty data).

Table 1: Life-history parameters for gag grouper

Variable	Description
$A = 20$	Age of plus group
$L_\infty = 131$	Mean asymptotic length
$k = 0.14$	Growth coefficient
$t_o = -0.37$	Time at zero length
$\alpha = 1.229e-5$	Allometry in $W_a = \alpha l_a^\beta$
$\beta = 3$	Allometry in $W_a = \alpha l_a^\beta$
$\tilde{a} = 10.8$	Age at 50% male
$\sigma_{\tilde{a}} = 1$	Standard deviation in $\tilde{a}$
$W_m = 1.35$	minimum weight at maturity

Gag are protogynous hermaphrodites (start life as a female and transition to male); therefore, age-specific fecundity is a function of both maturity-at-age and proportion of the population that is female, i.e.,

$$f_a = \max\left\{(w_a - W_m)\left(1 - \frac{1}{1+\exp(-(a-\tilde{a})/\sigma_{\tilde{a}})}\right), 0\right\}$$

The time series observations consist of the historical removals c_t (catch plus dead discards), a measure of relative abundance (CPUE) that is assumed to be proportional to the vulnerable biomass with lognormal observation errors, and a measure of the mean-age of the catch ($\bar{a}_t = e^{\nu_t}\sum_a a p_a$), where p_a is the proportion-at-age in the catch, and ν_t is a lognormal measurement error.

In order to utilize all of the available information, your assessment model will have to include predictions about the catch-at-age (in order to calculate p_a) and vulnerability-at-age. If you plot the apparent trend information in the CPUE data, you'll notice that the population starts at low abundance in 1963 and increases at a near constant rate until the 1980s. Your assessment model will require an additional parameter that initializes the population at some level less than the unfished carrying capacity (i.e., B_{1963}). A elegant way to do this is to initialize the population at some fished equilibrium value, and estimate the equilibrium exploitation rate (U_e) in 1963.

You have two options for parameterizing the model: the first is to use the traditional approach where B_o and κ are the leading parameters, the second is to derive B_o and κ from the leading management parameters (e.g., Forrest et al., 2008; Martell et al., 2008) C_o and U_o (which correspond to MSY and U_{msy}). Table 2 summarizes the parameter vectors and the observation models for predicting CPUE and mean age of the catch. Modify the existing Age Structured Assessment Model (used in the first assignment) to accommodate transition to male and fecundity schedules, calculate mean age of the catch and its corresponding likelihood. There should be sufficient information in the time series data to estimate all of the parameters; however, if you feel its necessary to include prior information, suggested prior density functions are provided in Table 2.

For your assignment:

1. Provide two plots comparing fits to the CPUE and mean age data and a corresponding table with estimated parameters and standard deviations. Note your results are sensitive to the initial values of Θ, so see if you can find a unique vector Θ that fits the data best.

2. Describe the statistical confounding between the estimated parameters (i.e., the correlation matrix). Can you recommend additional information or a deliberate experiment that would help resolve confounded parameters that impact management advice?

3. Calculate the exploitation and biomass reference points and provide a plot showing the time-history of the biomass and exploitation rates relative to the reference points (e.g., Figure 1). Note if you have used B_o and κ as your leading parameters, then use the equilibrium model from Assignment 1 to find U_o and determine the appropriate biomass reference point. If you have used the management oriented approach, then use estimate of U_o to calculate the biomass reference point. What is the current status of the stock? (Note, if you are struggling with getting `optim` to work, you can still base your results on a best guess for Θ)

Table 2: Estimated parameters, observation models, likelihoods and prior distributions.

Estimated parameters

$$\Theta = \{B_o, \kappa, M, U_e, \hat{a}, \tau_{\hat{a}}, \tau_y, \tau_{\bar{a}}\}, \text{ or}$$

$$\Theta = \{C_o, U_o, M, U_e, \hat{a}, \tau_{\hat{a}}, \tau_y, \tau_{\bar{a}}\}$$

Observation models

$$y_t = qB_t e^{\epsilon_t}$$

$$\tilde{a} = e^{\nu_t} \sum_a a p_a$$

$$p_a = \frac{N_a v_a u_t}{\sum_a N_a v_a u_t}$$

Negative loglikelihoods

$$\ell_y = \frac{n}{2}\left(\ln(2\pi) + \ln(1/\tau_y)\right) + \frac{\tau_y}{2}\sum_t \epsilon_t^2$$

$$\ell_{\bar{a}} = \frac{n}{2}\left(\ln(2\pi) + \ln(1/\tau_{\bar{a}})\right) + \frac{\tau_{\bar{a}}}{2}\sum_t \nu_t^2$$

Prior densities

$$P(B_o) \sim \text{lognormal}(\mu, \sigma)$$

$$P(\kappa) \sim \text{lognormal}(\mu, \sigma)$$

$$P(M) \sim \text{lognormal}(\mu, \sigma)$$

$$P(U_e) \sim \text{beta}(\alpha, \beta)$$

$$P(\hat{a}) \sim \text{normal}(\mu, \sigma)$$

$$P(\tau_{\hat{a}}) \sim \text{gamma}(\alpha, \beta)$$

$$P(\tau_y) \sim \text{gamma}(\alpha, \beta)$$

$$P(\tau_{\bar{a}}) \sim \text{gamma}(\alpha, \beta)$$

R code:

R-code for producing Figure 1; note that R is a list object containing reference points `R$Uo`, `R$Bmsy`, biomass and exploitation rate vectors `$R$Bt$` and `R$Ut`.

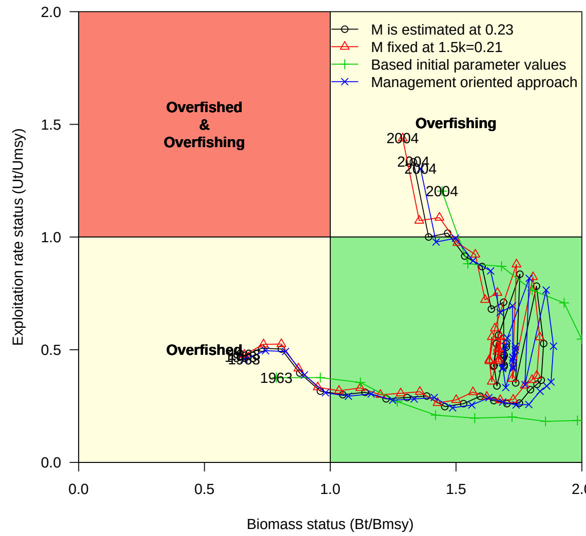

Figure 1: Maximum likelihood estimates of the historical status of the GOM gag grouper stock relative to biomass and exploitation rate reference points.

```
stats.plot <- function(R,add=F,...)
{
par(mfcol=c(1,1),xaxs="i",yaxs="i")
bstat<-R$Bt[1:length(yr)]/R$Bmsy
ustat<-R$Ut/R$Uo
if(!add) {plot(bstat,ustat,type="o",
    xlab="Biomass status (Bt/Bmsy)",
    ylab="Exploitation rate status (Ut/Umsy)",
    ylim=c(0,2),xlim=c(0,2),pch="x")
rect(0,1,1,2,col="salmon")
rect(0,0,1,1,col="lightyellow")
rect(1,1,2,2,col="lightyellow")
rect(1,0,2,1,col="lightgreen")
}
lines(bstat,ustat,type="o",...)

text(bstat[c(1,n)],ustat[c(1,n)],paste(yr[c(1,n)]))
text(0.5,1.5,"Overfished\n&\nOverfishing",font=2)
text(0.5,0.5,"Overfished",font=2)
text(1.5,1.5,"Overfishing",font=2)
}
```

References

Forrest, R. E., Martell, S. J. D., Melnychuk, M. C., and Walters, C. J. (2008). An age-structured model with leading management parameters, incorporatig age-specific selectivity and maturity. *Can. J. Fish. Aquat. Sci.*, 65:286–296.

Martell, S. J. D., III., P. W. E., and Walters, C. J. (2008). Parameterizing age-structured models from a fisheries management perspective. *Can. J. Fish. Aquat. Sci.*, 65:1586–1600.