Biology 408 & Zoology 527
Assignment 10
Due January 18, 2006

Virtual Population Analysis: Northern Cod case study 1962-1991.

Virtual Population Analysis(VPA) is one of the most widely used and abused methodologies in fisheries. VPA reconstructs population abundance using estimated catches at age over time($C_{a,t}$) (a=age, t=year, with a going from 1 to A ages and t going from 1 to T years). Develop a spreadsheet system for doing the basic reconstruction and for "tuning" (fitting) the assessment to relative abundance time series data, where relative abundance (Look below the blue shaded area on the spreadsheet) y_t in any year is typically and index proportional to the exploitable biomass (sum of numbers at age x vulnerability x weight at age). Apply this system to the northern cod (2J3KL) data (codvpa.xls) on the web site (http://www.zoology. ubc.ca /∼ bio408).

For discrete (seasonal) harvesting, the basic reconstruction equation for any cohort (fish born in one year) is just the table of values

$$N_{a,t} = \frac{N_{a+1,t+1}}{S} + C_{a,t} \tag{1}$$

- S is the natural survival rate, a is age, t is time
- N, C, are the age specific numbers and catch in numbers

The problem with this equation is to provide starting estimates of $N_{a+1,t+1}$ for all ages in the last year, T ($N_{a,T}$, a<=A) and for the last age in all years ($N_{A,t}$, t<T). $N_{A,t}$ is usually set initially to $C_{A,t}$. This can later be refined by assuming $N_{A,t} = \frac{C_{A,t}}{U_t}$ where U_t is the exploitation rate on fully vulnerable age classes($f \rightarrow A$) and is calculated as $\mathrm{U_t} = \sum_{\mathrm{a=f}}^{\mathrm{A-1}} \mathrm{C_{a,t}} \Big/ \mathrm{N_{a,t}}$ The summation is over fully vulnerable numbers which begins at around age 8 for cod(note this formula will give you garbage until the recursion formula for N is in place in your spreadsheet's N cell area). Generally we solve the terminal year(T) problem by assigning (or estimating) "terminal exploitation rates" $U_{a,T} = U_T v_{a,T}$(where $v_{a,T}$ are age specific vulnerabilities) then take $N_{a,T} = \frac{C_{a,T}}{U_{a,T}}$. U_T is a "free parameter" for fitting to relative abundance data, for the "fully vulnerable ages a=f, f+1,...,A. You need to test several possible strategies for estimating the "terminal relative vulnerabilities" $v_{a,T}$. The initial values provided are only to get you started. One way is just to plug in arbitrary values of these $v_{a,T}$ obtained by "iterating" your calculation and getting average $v_{a,T}$ from earlier years in the assessment($v_{a,t} = \frac{C_{a,t}}{N_{a,t}U_t}$) for such earlier years. Another is to calculate average $v_{a,T}$ over a short "window" of years t=K to T-1(e.g. last 3 or 5 years), for ages a<f(f is the first age at full vulnerability), and using these for year T. Still another is to calculate average $v_{a,T}$ over the short window, then take $v_{a,T}$ to be the TREND function (linear projection) of these values to year T. The reason you have to try several options is that $v_{a,T}$ can change rapidly under conditions like fishery collapse, when fishermen often start targeting smaller fish and/or growth rates increase.

To estimate U_T, set up a table function to show how SS evaluated at the maximum likelihood estimate of $ln(q)$ varies with U_T. Here $SS = \left(Z_t - \bar{Z}\right)^2$, where $Z_t = \ln\left(\frac{y_t}{VB_t}\right)$, y_t is survey relative abundance for year t (1980-91 for the cod example), and VB_t is vulnerable biomass in year t from VPA calculated as $VB_t = \sum_{a=1}^{A} B_{a,t} v_{a,t}$. $\bar{Z}$ is the MLE of $ln(q)$ which is calculated as $\bar{Z} = \frac{\sum_t Z_t}{n}$ where n is the number of survey data points. A good touch here is to parameterize the model by having VB_T be a leading model parameter , while setting U_T=(biomass catch in year T)/VB_T; then you can plot a probability distribution for VB_T or U_T, where the marginal probability for each B_T value is proportional to $SS^{-\frac{(n-1)}{2}}$.

In your report provide:

- Time series (1962-1991) for the 3+ and 7+ biomass, and harvest rate.
- Marginal posterior distribution for U_T or B_T.
- A forward projection of the population using some recruitment(age 2) vs. spawning biomass relationship and estimate the time it takes the population to recover to pre 1962 biomass levels. A reasonable assumption is that the spawning biomass is equal to the vulnerable biomass. Assume Beverton-Holt recruitment using the equation $R_t = S_o SB_{t-2}/1 + kSB_{t-2}$ Where S_o is the maximum survival rate, SB is the spawning stock biomass, R the age two recruits and k is a scaler parameter. Note that a recruitment relationship should be fit assuming log normal error.