FISH 103

The stock equation

The stock equation for a single yearclass and year is:

$$N_t = e^{-Z_t} N_0$$

where N_0 is the stock size at time $t = 0$, N_t the stock size at time t and Z_t is the total mortality rate at time t.

- Given $N = 1000$ at the beginning of the first year and $Z = M = 0.2$, compute and plot the development of the yearclass for 6 years.

  You can do this in R using a for–loop and store N at each iteration.

  In this example a vector is created and N stored in the vector.

  ```
  t <- 1:6
  Z <- 0.2

  N <- rep(0, length(t))
  N[1] <- 1000

  for(i in t){
    N[i+1] <- exp(-Z)*N[i]
  }
  ```

  Alternatively, each new value of N can be combined using `c` with the previous values. There is also an example in your class notes.

  ```
  t <- 1:6
  N <- 1000
  for(i in t){
    N <- c(N, exp(-Z)*N[i])
  }
  ```

- Try this for different values of Z. A source file could be written which runs the loop and also plots the results.
- What happens to the curve if you introduce fishing mortality for the older ages? e.g. $Z = 0.2$ for the first 3 years and $Z = 0.5$ for the next 3 (i.e. $M = 0.2$ and $F = 0.3$). To do this use the same script as before but edit it so that you have a vector describing Z (e.g. `Z <- c(rep(0.2,3),rep(0.3,3))`) and in each loop use `Z[i]`.
- If e^{-Z} is the proportion surviving the year, with $Z = 0.7$ what percentage of the population die in that year? If $N = 23764$ at the beginning of the year how many fish die?
- If $M = 0.142$ and there is no fishing, what percentage of the stock will die from natural causes?
- If $M = 0.34$ and there is no fishing, what proportion of the stock will survive the year?

Development of a yearclass in numbers and biomass

Given mean weights at age:

age	3	4	5	6	7	8	9	10	11	12	13	14
wgt(kg)	1.28	1.88	2.60	3.70	4.42	5.54	6.64	7.98	9.06	9.94	10.63	10.99

Natural mortality $M = 0.2$ and a starting population $N = 1000$ at age 3.

- Compute the number surviving to the next year and use the mean weights at age to calculate the biomass at age. Plot the number and biomass. This is almost the same as the example above – there is also an example in your class notes.
- Then introduce fishing mortality for the older ages and plot the results.

Catch curve analysis

The catch of a yearclass in the following year can be written as:

$$C_{a+1,y+1} = e^{-Z} C_{a,y}$$

With Z constant, this can be written as:

$$\ln C_{a+1,y+1} = \ln C_{a,y} - Z$$

or as

$$Z = \ln C_{a,y} - \ln C_{a+1,y+1}$$

Using this equation, given the catch of a cohort the mortality can be estimated.

- Save at least one of these tables of catch at age data as a text file.

  www.hafro.is/∼lorna/codcatch
  www.hafro.is/∼lorna/haddockcatch
  www.hafro.is/∼lorna/saithecatch

  The data represent catches/landings in numbers by age and year in millions.

- Read the data into R using `scan`. e.g.

  ```
  catch <- matrix(scan("catchdata", skip=1), byrow=T, ncol=9)
  ```

  `scan` reads text by row and we do not want the first row of the file (so use `skip=1`). When we save the data as a matrix we need to know how many columns (`ncol=9`) the matrix should have – this will depend on the dataset.

- Compute the average catch in numbers at age over all years and plot against age. (`apply`)
- Modify the catch table so that a cohort (yearclass) is represented by a row.

  There are several ways to do this, one method is this:

  First transform the data matrix into a data.frame, with columns for year, age, number.

```
ages <- 2:9     # this will depend on the catch data
year.vec <- rep(catch[,1], length(ages))
                # repeat the years for each age
age.vec <- rep(ages, rep(nrow(catch), length(ages)))
                # repeat the ages for each year
numb.vec <- as.vector(catch[,-1])
                # the catch numbers as a vector
                # R reads the matrix by by column

# then put the data into a data.frame
catch2 <- data.frame(year = year.vec, age = age.vec, number = numb.vec)
```

A column with yearclass is then added to `catch2` — e.g. year - age. Create this column. (`catch2$yclass <- catch2$year - catch2$age`). To generate a table of catch numbers with yearclass as the rows then use `tapply`. e.g.

```
catch3 <- tapply(catch2$number, list(catch2$yclass, catch2$age), sum)
```

`list` within `tapply` is used to apply the operation (e.g. sum) using more than one column and `sum` can be used as there is only one cell for each yearclass, age combination - you can check this is you wish using `table`.

- Copy the new catch table and ln transform the data.
- Plot the catch curves of the cohorts from the original data and the transformed data (ie $\ln C$ against age and C against age). You can delete or ignore the rows where most cells are `NA`. You do not need to plot all years together – but plot some years together in the same plot.

  If the transformed data are in an object called `ln.catch` the following commands will plot the data:

```
ages <- dimnames(ln.catch)[[2]]
yl <- range(na.omit(ln.catch))
plot(ages, ln.catch[1,], ylim=yl, xlab="age", ylab="ln(catch)", type="n")
for(i in 1:10) lines(2:9, ln.catch[i,], col=i+1)
```

  Or like this:

```
ages <- dimnames(ln.catch)[[2]]
matplot(ages, t(ln.catch[1:5,]), ylim=yl, xlab="age", ylab="ln(catch)",
type="l", col=1:5)
```

  In this case, `matplot` assumes the data are to be plotted by column and as the cohort data in `ln.catch` is by row, the matrix needs to be transformed using `t`. Try `t` with a small matrix so see how it works. e.g. `z <- matrix(c(2,3,4,5), ncol=2)`.

  To add a legend with the year to either plot do something like this:

```
yrs <- dimnames(ln.catch)[[1]][1:10]
legend(4,-2,paste(yrs), lty=1, col=2:11, bty="n")
```

- Add another line to the plot to represent the mean catch curve for all years. If you use `lwd=2` in the `lines` command it will be thicker than the other lines. If you have `NA` values in the matrix including `na.rm=T` in the `apply` command will ignore all missing values.
- Which age do you think is fully recruited to the fishery?
- Estimate Z for the oldest ages by calculating the slope from a regression of $\ln C_{ay}$ against age. (`lm()`) And add the calculated line to the plot using `abline`. If you use an object calculated from `apply` in the linear regression you will need to do e.g.

```
ydat <- as.vector(apply(ln.catch,2,mean,  na.rm=T))[4:9]
xdat <- 5:10
fit <- lm(ydat ~ xdat)
```

This is because `lm` will not accept the output from `apply` directly.

- Which ages did you calculate Z from and why? Are there any problems in fitting a line to these data?
- Do you think that Z will be constant over all the cohorts?

Mortality by age

- From the table of ln(catch) by cohort, create another table containing the difference in ln(catch) from one year to the next. ie $\ln(C_{t+1}) - \ln(C_t)$ which estimates -Z just as the first catch curve analysis did. This can be done by creating another matrix and subtracting one from the other – where one contains e.g. ages 3 to 9 and the other ages 2 to 8.
- Plot these cohorts. You may wish to exclude some ages or plot the cohorts in groups rather than for all years.
- Calculate the average Z by age.
- Are there age groups over which Z is constant?
- Does the pattern vary with time?