Háskóli Íslands	**09.51.70 Fiskifræði**	**Raunvísindadeild**
Laugardagur	**13. maí 2006**	**kl 09:00-12:00**
Permissible accessories: Notes, books and all types of calculators	**Note** that equipment such as laptops and mobile phones are not permittted	**The weight** of each problem is given.

Solutions

1. (10) Fig. 1 shows yield per recruit vs fishing mortality for a range of natural mortalities (M=0.1, 0.2, 0.3, 0.4) where Z has been estimated at 0.95. Keep this figure in mind when you give justified answers to the following:

(a) In the case of a well-managed situation (low F), if M suddenly increased (from 0.1 to 0.2), should one the increase or decrease F to obtain as much yield (per recruit) as possible? ?
(b) If M was earlier underestimated and a revised estimate indicates it to be higher, does this increase or decrease the F in the assessment?
(c) What is F and what will the yield per recruit be if natural mortality is $M = 0.1$?

Solution:

(a) In the case of a low fishing mortality, the F has corresponded to a value no greater that F_{max}. If M suddenly increases, this corresponds to moving vertically between the curves since F is now fixed. Curves for higher M have higher F_{max} and it will be better to increase F.

Note that this is also obvious: If M increases and nothing else happens, then one needs to fish harder in order not to lose the fish to natural mortality.

[Note that in many cases this is only a marginal benefit and one would rarely recomment this action]

(b) Since $Z = F + M$ is fixed, increasing M will lead to a decrease in the estimated F.

(c) Since $Z = 0.95$ and $M = 0.1$, one must have $F = 0.85$. Reading off the curve for $M = 0.1$ indicate Y/R just below 4kr/recruit about 3.75kr/recruit.

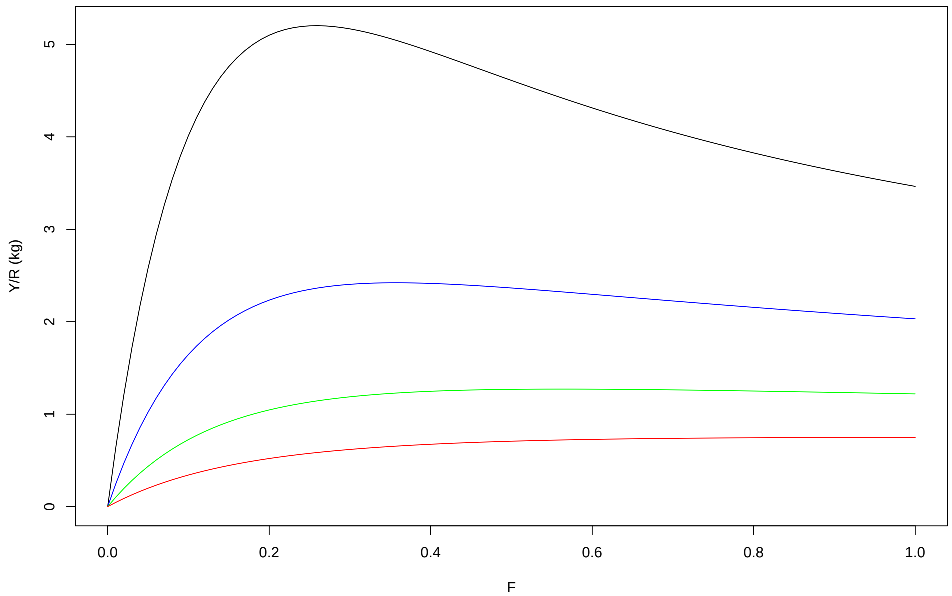

Figure 1: Yield per recruit for various values of M
Mynd 1: Afrakstur á nýliða miðað við mismunandi M

2. (15) The following table gives mean weight (kg) by age, the selection pattern, natural mortality, proportion mature and an estimate of the abundance of the different age groups (number of fish) in a small stock at the beginning of the year 2006. It is believed that the average fishing mortality on 5-6 year old fish was about 0.7. A recruitment forecast indicates that recruitment in 2007 will be 120 thousand individuals.

(a) Predict the stocksize in numbers by age at the beginning of the year 2007.

(b) Predict the catch in tonnes during the year 2007 assuming no change in effort.

Take care of the units.

Age	w_a	s_a	M_a	p_a	N_a
1	0.008	0.05	0.2	0.00	90 000
2	0.050	0.25	0.2	0.00	30 000
3	0.150	0.50	0.2	0.01	30 000
4	0.300	0.75	0.2	0.05	20 000
5	0.500	1.00	0.2	0.30	2 000
6	0.750	1.00	0.2	0.75	5 000

Solution:

This is best solved by adding columns to the table

Age	w_a	s_a	M_a	p_a	F	Z	$N_{a,2006}$	$N_{a,2007}$	C_a	Y_a
1	0.008	0.05	0.2	0.00	0.035	0.235	90 000	120 000	3 743	30
2	0.050	0.25	0.2	0.00	0.175	0.375	30 000	71 151	10 383	519
3	0.150	0.50	0.2	0.01	0.350	0.550	30 000	20 619	5 551	833
4	0.300	0.75	0.2	0.05	0.525	0.725	20 000	17 308	6 463	1939
5	0.500	1.00	0.2	0.30	0.700	0.900	2 000	9 686	4 471	2235
6	0.750	1.00	0.2	0.75	0.700	0.900	5 000	813	375	281
Total										5837

Computations are done using the usual stock and catch equations. The stock equation is applied diagonally in the table as usual (e.g. $20619 = 30000e^{-0.375}$).

Notice that since the units of the numers are just individuals and the weights are in kg, the yield is in kg. Since the request was for tonnes, the answer is **5.84 t**

3. (20) Use the number in problem (2) as needed to compute the yield per recruit and spawning stock biomass per recruit for $F = 0.4$ (on ages 5-6).

Solution:

Again, the best method is to expand the original table. We assume $F = 0.4$ on ages with a flat selection pattern (ages 5-6). It is easier to start with N=1000 but N=1 is what is needed at the end.

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     w    s   M    p      N Fvec    Z cumZ       N     C     Y     S
1 0.01 0.05 0.2 0.00 90000 0.02 0.22 0.00 1000.00 17.95  0.14  0.00
2 0.05 0.25 0.2 0.00 30000 0.10 0.30 0.22  802.52 69.33  3.47  0.00
3 0.15 0.50 0.2 0.01 30000 0.20 0.40 0.52  594.52 98.00 14.70  0.89
4 0.30 0.75 0.2 0.05 20000 0.30 0.50 0.92  398.52 94.08 28.22  5.98
5 0.50 1.00 0.2 0.30  2000 0.40 0.60 1.42  241.71 72.71 36.35 36.26
6 0.75 1.00 0.2 0.75  5000 0.40 0.60 2.02  132.66 39.90 29.93 74.62
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Y/R:  0.1128144

S/R:  0.1177454
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(final results are in kg per recruit).

4. (25) Fig. 2 shows (a) yield per recruit, (b) spawning stock biomass per recruit, (c) a Beverton-Holt stock-recruitment relationship ($R = \alpha S/(1+S/K)$) along with replacement curves corresponding to F=0, 0.25, 0.35 and F_{crash} and finally (d) equilibrium catch vs spawning stock biomass. Some of the figures include lines for reference (corresponding to the same F-values).

(a) Find F_{crash}
(b) Compute the size of the equilibrium SSB at $F = 0.25$.
(c) What will the (average) recruitment be at $F = 0.25$?
(d) If the stock starts at 250Kt, where will it go if 20Kt are caught each year?
(e) If the stock starts at 50Kt, where will it go if 20Kt are caught each year?
(f) What will the (average) recruitment (eventually) become under a moratorium?

Data (in some cases the figures alone can be used):

F	Y/R	S/R
0.00	0.0	27.8
0.25	2.3	10.7
0.35	2.4	8.0
1.10	2.0	2.0
1.20	1.9	1.8
1.30	1.9	1.6

Known constants: $\alpha = 0.5621$, $K = 20000$(t).

Solution: The quantitative approach is to use the data and add a couple of columns to the table. The esuilibrium SSB is given by $S = K(\alpha S/R - 1)$, recruitment by $R = \alpha S/(1 + S/K)$ and yield by $Y = R(Y/R)$.

	F	Y/R	S/R	S	R	Y
1	0.00	0.0	27.8	292514.15	10522.09	0.00
2	0.25	2.3	10.7	100284.22	9372.36	21556.42
3	0.35	2.4	8.0	69932.13	8741.52	20979.64
4	1.10	2.0	2.0	2483.03	1241.52	2483.03
5	1.20	1.9	1.8	234.73	130.41	247.77
6	1.30	1.9	1.6	-2013.57	-1258.48	-2391.12

(a) If follows that F_{crash} is about 1.20.

(b) 100284 tonnes

(c) 9372 thousands or 9.4 millions.

(d) Draw a horizontal line at $Y = 20000$ in panel (d). This intersects the curve at two locations. Starting at 250Kt implies that the stock will decrease so the upper intercept is the correct answer (SSB about 150 000t).

(e) The equilibrium yield at 50Kt is (slightly) lower than 20Kt so one would expect the stock to decline and collapse if a constant catch of 20Kt is maintained when the stock starts at this level.

(f) $R_\infty = \alpha K = 11242$ or 11 millions.

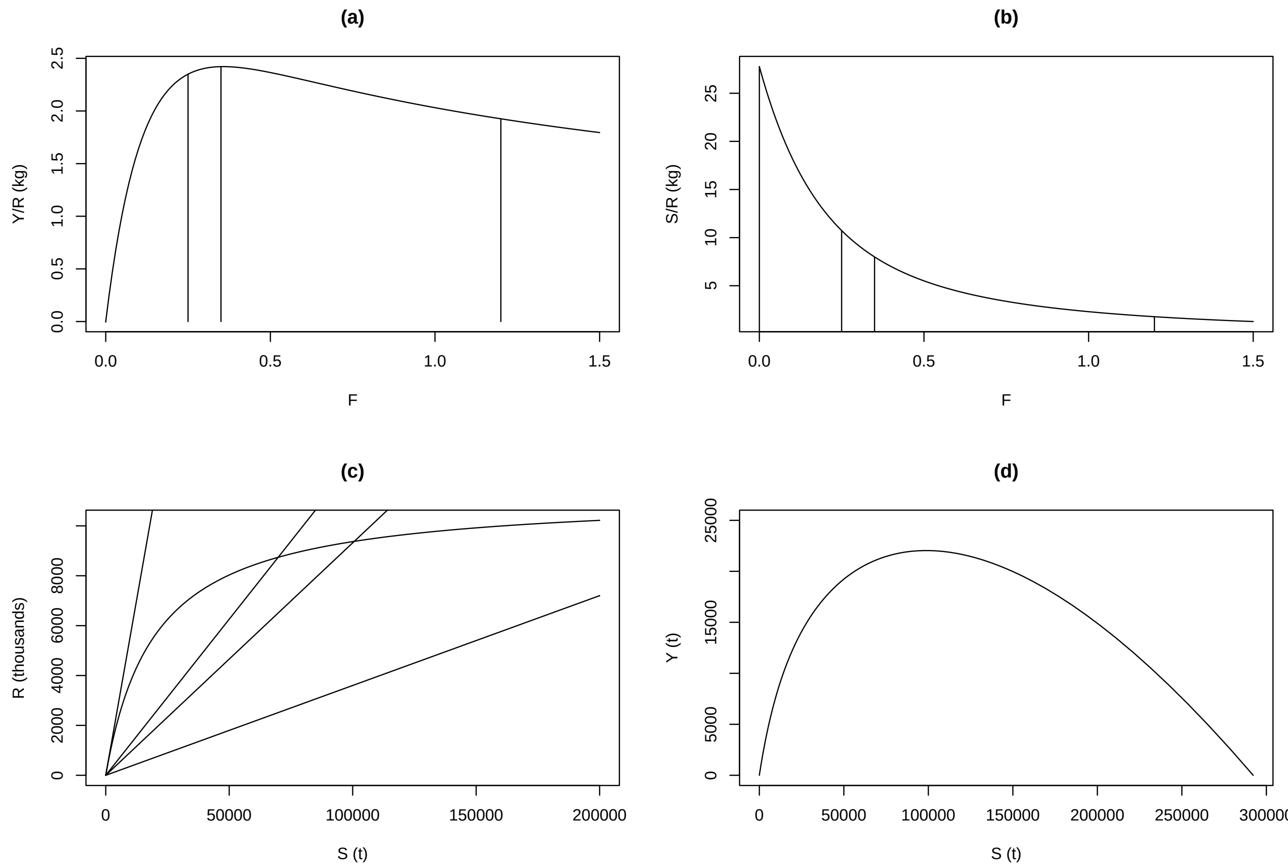

Figure 2: Various figures, see text.
Mynd 2: Ýmsar myndir, sjá texta.

5. (10) Several tags were placed in the 1999 yearclass of the sillystock when it came under moratorium at the beginning of year 2000. During the first following year a survey caught large numbers of tagged fish. In the fourth survey year, however, the number of tagged fish caught was only 5% of the number caught in the first year. Estimate natural mortality.

Solution:

For ease of mind, set up a table with exact timings and notation:

Year	Survey year	Measurement
2001	1	$I_1 = qN_1$
2001	2	$I_2 = qN_2$
2001	3	$I_3 = qN_3$
2001	4	$I_4 = qN_4$

Recall that one would normally assume $N_{a+1} = N_a e^{-Z}$ where $Z = M$ since the stock is under moratorium and we assume constant natural mortality. We obtain

$$N_4 = N_3 e^{-M} = N_2 e^{-2M} = N_1 e^{-3M}$$

and since each of these is proportional to the index which dropped to 5% of the initial value we have

$$e^{-3M} = 0.05$$

and the result follows: $M = -ln(0.05)/3 = 0.999$.

Note that the only issue here is counting years. There are 3 years between surveys in year 1 and year 4 and total mortality over 3 years is e^{-3M}.

6. (20) The coefficients α and K describe the shape of the Ricker curve.

(a) It has been claimed that the maximum of the Ricker stock-recruitment curve corresponds to the maximum yield. Is this (always) correct? (justify the answer).

(b) If the yield per recruit is a strictly increasing function of fishing mortality and the stock-recruitment relationship is of the Ricker type, which is larger, K or B_{MSY}?

[Hint: Draw the Ricker curve along with a replacement curve which passes through the peak. Put the same F into a Y/R graph. Now note, how R and Y/R change when fishing more or less that corresponding to this fishing mortality. Draw whatever conclusions can be drawn on how the yield Y changes as F decreases or increases and thus find whether F_{MSY} is larger or smaller than this F and then answer the original question.]

(c) If SSB is measured in tonnes and the number of individuals is in millions, what is the unit of the coefficient α in the Ricker curve?

Solution:

(a) Not true: The S-R curve contains no information on growth. The Y/R-curve might well tell you that it is better to have many fewer recruits as long as they grow fast.

(b) Follow the hint. Let F be the fishing mortality which corresponds to a replacement curve through the max on the Ricker curve. Draw the curve and the replacement line.

Once we have the replacement curve going through the peak of the S-R curve and look at the same F on the Y/R-graph we note the following: If we move from this F in either direction on the S-R curve the recruitment drops. If we move to the left, towards lower F on the Y/R curve, then Y/R drops. So when we move towards lower F, both recruitment R and yield per recruit, Y/R drop. Hence since both components drop for all lower values of F, we also get lower values of yield, $Y = (Y/R)R$.

It follows F_{MSY} can not be lower that the F corresponding to the maximum R on the Ricker curve. But if $F_{MSY} \geq F$ then the equilibrium biomass, B_{MSY} corresponding to F_{MSY} must be the smaller of the two: $B_{MSY} \leq K$.

(c) Look at the equation: $R = \alpha S e^{-S/K}$. For the exponent to make sense, K has to have the same units as S so the exponent becomes unitless. Since S is in tonnes and R is in millions, α must convert from tonnes to millions, i.e. the units are

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millions/tonnes = 1 000 000 / 1 000 000 g
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or individuals per gram.