THOMPSON & BELL PREDICTION MODEL

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Prediction or predictive models predict the effect of different levels of fishing effort on the fish stocks in the future. Two prediction models that are widely applied are Thompson and Bell (1934) model and the Yield per recruit model developed by Beverton and Holt (1957). These models provide a direct link between fish stock assessment and fishery resource management. The Thompson & Bell Model is a widely used prediction model in assessing the optimum factor for increase or decrease of fishing effort to achieve maximum sustainable and economic yield of a commercially exploited species. This model builds on the output of age (as conceived in the original model) or length-based Virtual Population Analysis (VPA). The equations used for the VPA and cohort analysis can be transformed to predict future yields and biomass at different levels of fishing efforts; *i.e.*, the knowledge of the past fishery can be used to predict the future yields.

While predicting the impact of fishing intensity on yield and standing stock biomass of an exploited species in a geographic area, the Thompson and Bell model can add a third dimension – price – to the assessment profile through bioeconomic analysis, which can be done if value of the catch is provided as an input. The input parameters required for this model are

- L_1, L_2...L_n (length groups)
- K (annual growth coefficient – VBGF parameter)
- t_0 (age at zero length – VBGF parameter)
- L_∞ (asymptotic length – VBGF parameter)
- M (Natural mortality)
- Terminal F/Z (assumed to be 0.5)
- a (intercept of LWR)

- b (slope of LWR)
- Catch (in numbers) for each length group
- Yield and biomass output of Virtual Population Analysis
- Price

The output of the Thompson & Bell analysis are the predictions of catch in numbers, total deaths in numbers, the mean biomass and yield for a combination of different F and M values. The prediction made by length converted Thompson and Bell analysis is a prediction of the average long-term catches assuming recruitment to remain constant. The impact of changes in F on the yield, average biomass and value of the catch can be calculated to arrive at the Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY). The assumption in this method is that the stock remains in a steady state and all parameters, including recruitment remain constant.

The FiSAT package contains the Thompson and Bell yield and stock prediction for single/multispecies fisheries, and is perhaps the most widely used programme in India.

The LFSA package has two programmes, the TBYR and MIXFISH. The TBYR uses a special version of the Thompson and Bell yield and stock prediction model for the single stock, single fishery situation. The TBYR converts the stock estimates (in numbers) for length groups derived through LCOHOR analysis into age group stock estimates. This programme is better suited for long-lived species of 5 years or more since conversion of length groups to age groups in short-lived species is not easily done. MIXFISH is a length-based Thompson and Bell model with options for analysis of a mixed fishery. An advantage over the TBYR is that there is no need for conversion of length groups to age groups, and therefore it can be used for long-lived as well as short-lived species. Although designed for analysis of a mixed fishery, the MIXFISH also contains the single species analysis options as well as an option for mesh assessment. The output of MIXFISH indicates the total yield for various combinations of effort and L_{50}%.

Using the length-based Thompson & Bell model

Taking off from the output of length-based VPA, the steps involved in the Thompson & Bell analysis are –

- The i^{th} length class is

  $(L_i - L_{i+1})$

- Total mortality sequence is

  $Z_i = M + xF_i$, , where x is the multiplier used to raise or reduce the fishing mortality rates sequence, x = 1 for the current level of exploitation

- Population size of successive classes is

$$H_i = \left[\frac{L_\infty - L_i}{L_\infty - L_{i+1}}\right]^{\frac{M}{2K}}$$

$$N_{i+1} = N_i \left[\frac{\frac{1}{H_i} - x\frac{F_i}{Z_i}}{H_i - x\frac{F_i}{Z_i}}\right]$$

- Catch for each class is

$$C_i = [N_i - N_{i+1}]x\left(\frac{F_i}{Z_i}\right)$$

$$\overline{w_i} = a\left[\frac{L_i + L_{i+1}}{2}\right]^b$$

- Average weight for each length class is

$$Y_i = C_i\overline{w_i}$$

- Yield for each different length class is

$$V_i = Y_i\overline{v_i}$$

- Value for each length class is

$$\bar{N_i} = \frac{N_i - N_{i+1}}{Z_t \Delta t_i}$$

Using Excel for Thompson & Bell Analysis through Length-based Cohort Analysis

Vivekanandan (2002) discusses an example of the length-based Thompson and Bell analysis by using the data on the goatfish *Upeneus sulphureus* off Chennai and the price of different length groups of *U. sulphureus* in the landing center. In a later publication (Vivekanandan, 2005) uses the same example, but with more details on the method of analysis. The use of excel for Thompson & Bell analysis using the same data set is shown here –

The sample data set is **Length groups of goatfish *U. sulphureus* off Chennai during 2000.** The input data for Thompson & Bell analysis will be the output from length-based Virtual Population Analysis:

Length group (mm)	Fishing mortality	M factor	Total mortality	Mean body weight (g)	Number of survivors (000s)	Number caught (000s)	Yield (tonnes)	Mean biomass (tonnes)
50-59	0.6310	1.0498	1.5310	2.3	79073	4972	11.4	18.1
60-69	1.1775	1.0541	2.0775	3.7	67009	8218	30.4	25.8
70-79	1.4788	1.0592	2.3788	5.7	52510	8587	48.9	33.1
80-89	1.3861	1.0654	2.2861	8.3	38697	6476	53.8	38.8
90-99	1.2681	1.0729	2.1681	11.6	28016	4731	54.9	43.3
100-109	1.1779	1.0825	2.0779	15.6	19928	3477	54.2	46.0
110-119	1.0506	1.0950	1.9506	20.4	13794	2426	49.5	47.1
120-129	0.9217	1.1119	1.8217	26.2	9290	1648	43.2	46.8
130-139	0.7202	1.1361	1.6202	33.0	6032	992	32.7	45.5
140-149	0.6545	1.1737	1.5545	40.8	3801	684	27.9	42.6
150-159	0.3087	1.2404	1.2087	49.7	2176	245	12.2	39.4
160-169	0.2226	1.3911	1.1226	59.9	1217	136	8.1	36.6
170-179	0.2041	2.0884	1.1041	71.3	531	83	5.9	29.0
180-L_∞	0.9000	-	1.8000	84.2	82	41	3.5	3.8
Total							436.7	496.1

Step 1

Estimate Value of yield for each length class from per unit price data:

Length group (mm)	Fishing mortality	M factor	Total mortality	Mean body weight (g)	Number of survivors (000s)	Number caught (000s)	Yield (tonnes)	Mean biomass (tonnes)	Value (Rs/kg)	Value of yield (000 Rs)
50-59	0.6310	1.0498	1.5310	2.3	79073	4972	11.4	18.1	5	57.0
60-69	1.1775	1.0541	2.0775	3.7	67009	8218	30.4	25.8	5	152.0
70-79	1.4788	1.0592	2.3788	5.7	52510	8587	48.9	33.1	5	244.7
80-89	1.3861	1.0654	2.2861	8.3	38697	6476	53.8	38.8	5	268.8
90-99	1.2681	1.0729	2.1681	11.6	28016	4731	54.9	43.3	5	274.4
100-109	1.1779	1.0825	2.0779	15.6	19928	3477	54.2	46.0	15	813.6
110-119	1.0506	1.0950	1.9506	20.4	13794	2426	49.5	47.1	15	742.4
120-129	0.9217	1.1119	1.8217	26.2	9290	1648	43.2	46.8	15	647.7
130-139	0.7202	1.1361	1.6202	33.0	6032	992	32.7	45.5	15	491.0

Length group (mm)	Fishing mortality	M factor	Total mortality	Mean body weight (g)	Number of survivors (000s)	Number caught (000s)	Yield (tonnes)	Mean biomass (tonnes)	Value (Rs/kg)	Value of yield (000 Rs)
140-149	0.6545	1.1737	1.5545	40.8	3801	684	27.9	42.6	15	418.6
150-159	0.3087	1.2404	1.2087	49.7	2176	245	12.2	39.4	25	304.4
160-169	0.2226	1.3911	1.1226	59.9	1217	136	8.1	36.6	25	203.7
170-179	0.2041	2.0884	1.1041	71.3	531	83	5.9	29.0	25	147.9
180-L_∞	0.9000	-	1.8000	84.2	82	41	3.5	3.8	25	86.3
Total							**436.7**	**496.1**		**4852.5**

Step 2

Estimate the yield, biomass & value for varying Fishing mortality factors (F-factor). For example, the output shown under Step 1 is for F-factor = 1. The output for F-factor = 0.5 (*obtained by multiplying the fishing mortality of all length classes with 0.5*) will be

Length group (mm)	Fishing mortality	M factor	Total mortality	Mean body weight (g)	Number of survivors (000s)	Number caught (000s)	Yield (tonnes)	Mean biomass (tonnes)	Value (Rs/kg)	Value of yield (000 Rs)
50-59	0.3155	1.0498	1.2155	2.3	79073	2527	5.8	18.4	5	29.1
60-69	0.5888	1.0541	1.4888	3.7	69339	4390	16.2	27.6	5	81.2
70-79	0.7394	1.0592	1.6394	5.7	58238	4971	28.3	38.3	5	141.7
80-89	0.6931	1.0654	1.5931	8.3	47216	4129	34.3	49.4	5	171.4
90-99	0.6341	1.0729	1.5341	11.6	37725	3331	38.6	60.9	5	193.2
100-109	0.5890	1.0825	1.4890	15.6	29667	2711	42.3	71.8	15	634.4
110-119	0.5253	1.0950	1.4253	20.4	22813	2103	42.9	81.7	15	643.4
120-129	0.4608	1.1119	1.3608	26.2	17107	1592	41.7	90.5	15	625.6
130-139	0.3601	1.1361	1.2601	33.0	12407	1067	35.2	97.8	15	528.1
140-149	0.3272	1.1737	1.2272	40.8	8674	820	33.5	102.3	15	502.1
150-159	0.1544	1.2404	1.0544	49.7	5597	325	16.2	104.7	25	404.1
160-169	0.1113	1.3911	1.0113	59.9	3376	195	11.7	104.9	25	292.0
170-179	0.1021	2.0884	1.0021	71.3	1604	132	9.4	92.5	25	235.9
180-L_∞	0.4500	-	1.3500	84.2	304	101	8.5	19.0	25	213.6
Total							**364.7**	**959.8**		**4695.6**

Similarly, the output for F-facto r = 1.5 will be

Length group (mm)	Fishing mortality	M factor	Total mortality	Mean body weight (g)	Number of survivors (000s)	Number caught (000s)	Yield (tonnes)	Mean biomass (tonnes)	Value (Rs/kg)	Value of yield (000 Rs)
50-59	0.9465	1.0498	1.8465	2.3	79073	7340	16.9	17.8	5	84.4
60-69	1.7663	1.0541	2.6663	3.7	64754	11549	42.7	24.2	5	213.7
70-79	2.2182	1.0592	3.1182	5.7	47321	11139	63.5	28.6	5	317.5
80-89	2.0792	1.0654	2.9792	8.3	31662	7619	63.2	30.4	5	316.2
90-99	1.9022	1.0729	2.8022	11.6	20745	5035	58.4	30.7	5	292.0
100-109	1.7669	1.0825	2.6669	15.6	13328	3337	52.1	29.5	15	780.8
110-119	1.5758	1.0950	2.4758	20.4	8291	2091	42.7	27.1	15	639.9
120-129	1.3825	1.1119	2.2825	26.2	5006	1273	33.3	24.1	15	500.1
130-139	1.0803	1.1361	1.9803	33.0	2905	686	22.7	21.0	15	339.8
140-149	0.9817	1.1737	1.8817	40.8	1646	424	17.3	17.6	15	259.4
150-159	0.4631	1.2404	1.3631	49.7	834	137	6.8	14.7	25	169.7
160-169	0.3339	1.3911	1.2339	59.9	432	70	4.2	12.6	25	105.0
170-179	0.3062	2.0884	1.2062	71.3	173	38	2.7	9.0	25	68.6
180-L_{∞}	1.3500	-	2.2500	84.2	21	13	1.1	0.8	25	26.8
Total							**427.6**	**288.0**		**4113.9**

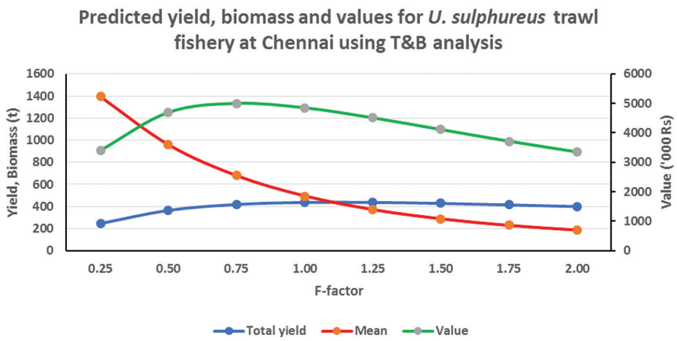
Step 3

Tabulate the predicted total yield, mean biomass and value obtained for a range of F-factors, starting from F-factor = 0. The yield and value will show continuous increase and then a steady decline, while the biomass will show a decline in quantity for increasing F-factors.

F factor	Total yield (tonnes)	Mean biomass(t)	Value (000 Rs)
0	0		0
0.25	245.2	1395.5	3400.9
0.50	364.7	959.8	4695.6
0.75	418.2	680.0	5001.5
1.00	436.7	496.1	4852.5
1.25	436.7	372.6	4513.2
1.50	427.6	288.0	4113.9
1.75	414.1	228.7	3717.8
2.00	399.2	186.3	3353.1

Step 4

The graph generated from the output data is given below. It can be observed that the yield increases from 245.2 t at F-factor of 0.25 to 436.7 t at F = 1.00-1.25 but decreases to 399.2 t at F = 2.00. The Maximum Sustainable Yield, the MSY (436.7 t) is obtained at the current fishing mortality level (F factor = 1.0). The mean biomass drastically decreases from 1395.5 t at F-factor 0.25 to 496.1 t at F-factor 1.00 and further to a mere 186.3 t at F-factor 2.00. The Maximum Sustainable Economic Yield, MEY is obtained at the F-factor 0.75 (Rs.50 lakhs). The interpretation of the results is that the present fishing level provides the MSY and increase in fishing effort will decrease the yield and drastically reduce the biomass. However, since the MEY is obtained at 75% of the present fishing effort, it is advisable to reduce the fishing effort to that level to realise better revenue.



Suggested Reading

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