Using Ecopath Model to Study the Trophic Relationship of Taungthaman Lake

Mi Mi Khaing[1] and Swe Thwin[2]

Abstract

Taungthaman Lake, is located near the Ayeyarwady river. A preliminary Ecopath model was constructed for Taungthaman Lake. The Ecopath software package which includes time-dynamic (Ecosim) and spatial simulation (Ecospace) sub-model was used to study the trophic relationship of some commercial fish species from Taungthaman Lake. The first approximation of a Taungthaman Lake Ecopath model was attempted. Ecopath, a predator-prey ecosystem modeling program was used to provide qualitative assessments for the predator-prey relationship of the dominant functional groups in the lake environment, an attempt was made to assemble the critical data sets required for the generation of the model and preliminary outcome.

Keywords: Ecopath, Ecosim and Ecospace, Trophic Relationship.

Introduction

Flood water fisheries are dynamic ecosystems in which environmental fluctuations and changing species compositions are common. Food webs, and the pathways of energy flow within the food web, also vary due to changes in river flow, water temperature, water column stratification, seasonal variation in biota, and ontogenetic changes in feeding strategies of constituent species. The primary policy objective within floodplains fishery of the river system has also undergone changes and a decline in catches has been reported although data supporting of these conclusions are still lacking. However, the major reasons for this development can be seen in the intensive fishing pressure combined with more difficult access to floodplains for the migration of brood stock and young fish. Most of the natural connections and canals, for regulating water inflow and outflow from floodplains, have been silted over and now permit flood water onto floodplains only when water levels are very high. This limits the number of brood stock fish and the period of time for their entry onto the floodplain water body for breeding. Fish stock and fisheries are adversely affected by gradual environment degradation.

[1] Demonstrator, Dr., Department of Zoology, Yadanabon University
[2] Professor and Head (Rtd.), Dr., Department of Marine Science, University of Mawlamyine

Increasing pressure on land, deforestation, catchments and conversion of land to agriculture have increased soil erosion. Such environmental degradation has had negative impacts on fish stocks.

One of the models Ecopath with Ecosim is being widely used as a tool for analysis of exploited aquatic ecosystems. EwE combines software for ecosystem trophic mass balance (biomass and flow) analysis (Ecopath) with a dynamic modeling capability (ECOSIM) for exploring past and future impacts of fishing and environmental disturbances.

Theoretical Background of Ecopath

The first Ecopath equation describes how the production term for each group (i) can be split in components. This is implemented with the equation,

Production = catches + predation mortality + biomass accumulation + net migration + other mortality; Eq. 1

Or, more formally,

$$P_i = Y_i + B_i \cdot M2_i + E_i + BA_i + P_i \cdot (1 - EE_i) \qquad \text{Eq. 2}$$

Where P_i is the total production rate of (i), Y_i is the total fishery catch rate of (i), $M2_i$ is the total predation rate for group (i), B_i biomass of the group, E_i net migration rate (emigration – immigration), BA_i is the biomass accumulation rate for (i), while $M0_i = P_i \cdot (1\text{-}EE_i)$ is the 'other mortality' rate for (i).

All weights are given in tonnes, area in km^2 and the time unit is a year.

P_i is calculated as the product of B_i, the biomass of *i* and $(P/B)_i$, the production/biomass ratio for *i*. The $(P/B)_i$ rate under most conditions corresponds to the total mortality rate, Z (Allen, 1971), commonly estimated as part of fishery stock assessments. The 'other mortality' is a catch-all rate including all mortality not elsewhere included.

The information about predator consumption rates and diets concerning a given prey can be used to estimate the predation mortality term for the group, or, alternatively, that if the predation mortality for a given prey is known can also estimate the consumption rates for one or more predators instead.

For parameterization Ecopath sets up a system with (at least in principle) as many linear equations as there are groups in a system, and it solves the set for one of the following parameters for each group, biomass, production/biomass ratio, consumption/biomass ratio, or ecotrophic efficiency. The model requires that the diet composition of all groups is known and at least three of the above basic parameters are known for each functional group.

In a model, the energy input and output of all living groups must be balanced. The basic Ecopath Eq.1 includes only the production of a group. Production equals predation + catches + net migration + accumulated biomass + other mortality. When balancing the energy balance of a group, other flows were considered. After the ‘missing’ parameters have been estimated so as to ensure mass balance between groups energy balance is ensured within each group using the second Ecopath equation

Consumption = production + respiration + unassimilated food Eq. 3

This equation is in line with Weinberg (1956), cited in Christensen, Walters and Pauly (2004) defined consumption as the sum of somatic and gonadal growth, metabolic costs and waste products. The main differences are that Weinberg focused on measuring growth, where focus on estimating losses, and that the Ecopath formulation does not explicitly include gonadal growth. The Ecopath equation treats this as included in the predation term (where nearly all gonadal products end up in any case).

Taungthaman Fishery

The water body of Taungthaman Lake located on the east bank of the Ayeyarwady River in Amarapura Township is approximately 600ha and is located between 96° 03′E and 21° 54′N. The lake supports an inland fishery about 1680 tons of fish annually, value of $ 840,000 and provides livelihood for nearly 5000 persons living nearby (FAO, 2002).). During rainy season the area of the Taungthaman Lake is about 607.02ha while the area of the lake is about 323.74ha during hot dry season. Historically, the lake was a flood basin of Ayeyarwady River. During the South West Monsoon, flood waters from the Ayeyarwady enters Taungthaman In, which then serves as a spawning and nursery area for river fish, including economically important species such as major carps and catfishes. At the end of the monsoon, water flow out of the In into the Ayeyarwady River carrying along the fish back into the river with the out flowing water. This seasonal migration of fishes supports a traditional Min-Won-Se fishery. During the past decade construction of sluice gates to hold the water during the dry season, and construction of highway embankments cut off the natural connections between Taungthaman Lake and the Ayeyarwady and

Myintnge river systems, and transformed it into a permanent lake. Reduced water flow especially during the low water levels is likely to impede fish migration and the movement of juvenile fish. The reduction in the water flow in the Taungthaman has been considered to be the reason for fishkills observed. The objective of this study is to assess the manner of management in order to maintain long-term sustainable food resources.

Materials and Methods

Collection of Data

Data collection was conducted from January 2006 to December 2006. Weekly visit were made to the fish landing place to record the stomach content of each species.

To estimate the Production/Biomass value, length frequency, length and weight data were weekly recorded at both main and secondary landing place. Daily production *of Wallago attu, Notopterus notopterus, Osteobrama belangeri, Oreochromis* sp., and *Labeo rohita* were obtained from Taungthaman fishery operator. Stomach contents were examined for all individuals of studied fish species. Large organisms are identified in the field and microscopic examination for small food items was done in the laboratory.

In the absence of reliable information on the composition and production of various components of zooplankton, phytoplankton and detritus group, the biomass, P/B and Q/B are adopted from other lake, Lake Kinneret based on the fact that these groups are not directly exploited and modified in the system. But the biomass data for phytoplankton is calculated using light and dark bottle method (APHA, 1979).

Trophic Group

Four main trophic groups were studied. They are (a) fish group (b) zooplankton (c) phytoplankton and (d) detritus.

Diet Composition

Diet composition must be entered for all consumers. The diet is expressed as the fraction each prey contributes (on a weight, energy, or volume basis) to the overall diet. In Ecopath ‘import’ to a system is the consumption of preys that are not a part of the system as it is defined. Import is thus different from migration, which is a production term. Import is treated as a ‘prey’ in the diet composition, and should be entered as a fraction of the total diet. Import is entered as the last food item.

The diet compositions of each group should sum to 1. In a trophic model such as constructed using the Ecopath approach and software, it is predation that links together the different groups in a system. Consumption for one group is mortality for another. Information on predation is important for understanding the dynamics of ecosystems. Quantitative information on diet composition is sparse-fish population dynamics has traditionally treated fish populations as if they were isolated. Much of the available information on diet compositions is expressed on a ‘percent occurrence’ basis or as ‘dominance’, both of which are of little use for quantification of diets. What are needed are measures based on weight, volume or energy content of the preys, which are all equivalent (MacDonald and Green, 1983).

Parameter Estimation
Production/Biomass Ratio (P/B)

Production refers to the elaboration of tissue, (whether it survives or not) by a species over the period considered, expressed in whatever currency has assumed for the contraction of mass-balance models, equal to production over biomass(Allen,1971). Therefore, use estimates of total mortality (Z) as input values for the production over biomass ratio (P/B) in Ecopath models.

Total Mortality from Average Length

Beverton and Holt (1957) showed that total mortality (Z=P/B), in fish population whose individual grow according to the Von Bertalanffy Growth function (VBGF), can be expressed by:

$$Z = P/B = \frac{K \cdot \left[L_\infty - \bar{L}\right]}{\bar{L} - L'} \qquad \text{Eq.4}$$

Where

L_∞ = asymptotic length or length infinity
K = VBGF curvature parameter
$\bar{L}$ = mean length
L' = the lower limit of the corresponding length interval

Consumption/ Biomass Ratios (Q/B)

Consumption is the intake of food by a group over the time period considered. It is entered as the ration of consumption over biomass (Q/B).

The consumption ratios for fish groups were estimated using the empirical equation of Palomares and Pauly (1998).

$$\log(Q/B) = 5.847 + 0.280 \cdot \log Z - 0.152 \cdot \log W_{\infty} - 1.360 \cdot T' + 0.062 \cdot A + 0.510 \cdot h + 0.390 \cdot d$$

Eq.5

Where

Z = total mortality

W_{∞} = asymptotic weight or weight infinity

T′ = mean annual temperature

A = aspect ratio

h = dummy variable expressing food type

d = dummy variable expressing food type

This relationship can be used only for fish species that use their caudal fin as the organ for propulsion.

Results

The output parameter of the model is represented in Table 3, the data input of biomass were derived using data on abundance, mean bodyweight and distribution area. P/B is calculated from equation (4) and Q/B from equation (5).

The data input of biomass of *Wallago attu* is 4.3 tons/km^2, P/B is 2.9 tons/km^2/year and Q/B is 8.91 tons/km^2/year. From the output parameter of the table), the EE value is 0.00, P/Q value is 0.325 and the trophic level of *Wallago attu* is 3.5. The specimens were top predator level in the ecosystem of Taungthaman Lake.

The data input of biomass of *N.notopterus* is 0.6 tons/km^2, P/B is 1.28 tons/km^2/year and Q/B is 9.78 tons/km^2/year. From the output of the table 3, the EE value is 0.975, P/Q is 0.131 and the trophic level of *N.notopterus* is 3.37 and places the second predator level in Taungthaman Lake.

The basic input of biomass of *O.belangeri* is 4.3 tons/km^2, P/B ratio is 2.24 tons/km^2/year and Q/B is 14.91 tons/km^2/year. From the output of the table (3). EE is 0.863 and P/Q is 0.15. In the lake, the trophic level of *O.belangeri* is 2.94.

The biomass of *Oreochromis* sp. is 280.73tons/km^2, P/B is 9.45 tons/km^2/year, Q/B is 18.9 tons/km^2/year. From the expression of the output table, EE is 0.015, P/Q is 0.5 and the trophic level of the specimen is 2.46.

L.rohita has the biomass of 11.6 tons/km^2, P/B 6.31 tons/km^2/year and Q/B 50.34 tons/km^2/year. The output parameter of this species reveals the EE of 0.095 and P/Q of 0.125. The trophic level of *L.rohita* in Taungthaman Lake is 2.05.

For zooplankton group, the basic input of biomass is 47.0 tons/km^2, P/B is 54.0 tons/km^2/year and Q/B is 190.0 tons/km^2/year. From the output parameter, EE is 0.99, P/Q is 0.284 and the trophic level is 2.0.

The basic input of biomass of phytoplankton is 120.0 tons/km^2 and P/B is 100.0 tons/km^2/year. From output of these, EE is 0.989 and the trophic level in Taungthaman Lake is 1.

The input of biomass of detritus is 75.0 tons/km^2. As a result, the EE value of 0.085 is obtained from Taungthaman Ecopath model.

Table 1.Basic input form for Taungthaman Lake in 2006**.**

Group Name	Biomass (t/km^2)	P/B (/year)	Q/B (/year)	EE
W.attu	4.328	2.900	8.910	
N.notopterus	0.618	1.280	9.780	
O.belangeri	4.3	2.240	14.910	
Oreochromis sp.	280.73	9.450	18.900	
L.rohita	11.626	6.310	50.340	
Zooplankton	47.0	54.000	190.000	
Phytoplankton	120	100.000		
Detritus	75.00			

Table 2.Direct composition form for Taungthaman Lake in 2006.

Prey\Predator	1	2	3	4	5	6
1. *W.attu*						
2. *N.notopterus*	0.020					
3. *O.belangeri*	0.200	0.100				
4. *Oreochromis* sp.	0.600	0.600	0.200			
5. *L.rohita*	0.180	0.010				
6. Zooplankton		0.290	0.650	0.460	0.050	
7. phytoplankton			0.150	0.480	0.650	1.000
8. Detritus				0.060	0.300	
9. Import						
10. Sum	1.000	1.000	1.000	1.000	1.000	1.000

Table 3. Parameters of the balanced Taungthaman Lake model in 2006. All biomass are expressed in web weight. Parameters estimated by ecopath are in bold italis.

Group Name	Trophic Level	Biomass (t/km^2)	P/B (/year)	Q/B (/year)	EE	P/Q
W.attu	***3.50***	4.328	2.900	8.910	***0.000***	***0.325***
N.notopterus	***3.37***	0.618	1.280	9.780	***0.975***	***0.131***
O.belangeri	***2.94***	*4.3*	2.240	14.910	**0.863**	***0.150***
Oreochromis sp.	***2.46***	280.73	9.450	18.900	***0.015***	***0.500***
L.rohita	***2.05***	11.626	6.310	50.340	***0.095***	***0.125***
Zooplankton	***2.00***	47.00	54.000	190.000	***0.99***	***0.284***
Phytoplankton	***1.00***	120	100.000		***0.989***	
Detritus	***1.00***	75			***0.085***	

Discussion

The result in the present report is only a preliminary output from the application of ecosystem modeling using Ecopath for the Taungthaman Lake. This model can be considered at best a first pass at the application of ecosystem modeling using Ecopath for Taungthaman Lake. In the model, respiratory value should not be negative.

Zooplankton, phytoplankton and detritus group, Q/B, P/B and biomass values are adopted from other areas due to lack of information, based on the fact that these groups are not directly exploited as quoted by Amorim, Duarte, Guerra, Morato, and Stobberup (2004). However, the biomass of phytoplankton was calculated using light and dark bottle method.

Although assumptions regarding P/B and Q/B for individual species are possible based on studies conducted elsewhere, the same cannot be done for biomass. In some instances, therefore, assumptions regarding the EE values were made, allowing for estimation of biomass by Ecopath once the other three input parameters were known.

However, in the case of exploited group such as fish groups, the model was allowed to estimate biomass and P/B. In such cases, fixed values of EE and gross conversion efficiency (P/Q) were assumed.

According to the output parameters of Lake Kinneret (Gayanilo and Christensen, 1997) and Lancester Sound Region (Mohammed, 1980), the

EE values of zooplankton are 0.96 and 0.806 respectively. The EE value of zooplankton is 0.91 in the Ecopath model of Okey and Pugliese (2001). In Taungthaman Lake, the EE value of zooplankton is 0.99.

According to the output parameters of Lake Kinneret (Gayanilo and Christensen, 1997), the EE value of phytoplankton is 0.78. The EE value of phytoplankton of 0.99 is given by Okey and Pugliese (2001). In Taungthaman Lake, the EE value of phytoplankton is 0.989.

Based on the observation of output parameter of Lake Kariba (Gayanilo and Christensen, 1997) the estimate of EE value of detritus is 0.054 and on the observation of Guinea-Biesau Ecopath model, the EE value of detritus is 0.104. In Taungthaman Lake, the EE value of detritus is 0.085.

According to the output parameters of Lake Kinneret, the EE value of tilapia was 0.17. In Lake Prakrama, the EE value of *O. mossambica* (0.95) and *O. niloticus* (0.5) were observed (Gayanilo and Christensen, 1997). The EE value of *O. nilotica* in Broa reservoir is 0.95 as reported by Angelinic and Petrere, (1996). The EE value of tilapia in Taungthaman Lake is recorded as 0.015 (2006).

An estimate of EE value of 0.00 at the top trophic level of Lancester Sound Region is given by Mohammed (1980). In Taungthaman Lake, the EE value of top trophic level is 0.00.

The model is stated to be not balanced if P/Q values of any species exceed 0.5. The P/Q value does not exceed 0.5 in this study. Therefore, the constructed model can be stated as balance of Taungthaman Lake.

Acknowledgements

I am greatly indebted to Professor Dr. Khin May Nyo, Head of Zoology Department, Yadanabon University, for accepting the chosen topic and providing available facilities in the department.

My profound gratitude goes to Dr. Swe Thwin, Professor and Head (Retired), Marine Science Department, University of Mawlamyine for his invaluable supervision, understanding, and criticisms of the manuscript.

I extend my thanks to U Myint Wai and U Min Maw Tun, leasable holders for their consent to collect the specimen. I acknowledge Ko Tun Tun and fishermen of Taungthman Lake Fishery in Amarapura Township, who provided me with necessary information with regard to the fishery.

Thanks are due to my friends and colleagues, especially Ko Myat Thu, Lecturer, Electronics Department, Mandalay Technological University, for their help rendered in various ways during the course of this work.

Finally, my heartfelt gratitude goes to my parents U Kyaw Htay and Daw Yi May Myint, my aunty, Daw Aye Aye Khaing and my sisters and brothers for their moral and financial support rendered throughout the study period, without which this work could not have been accomplished.

References

Allen, R. R. (1971) Relation between production and biomass. *J. Fish. Res. Board Can*, **28**:1573-1581

Althauser, L.L.(2003) *An Ecopath/Ecosim Analysis of an Estuarine food web:seasonal energy flow and response to river-flow related perturbations*, Depart-ment of Oceanography and coastal sciences, B.S., Texas A&M University. 107p

Amorim, P., G.Duarte, M.Guerra, T.Morato, and K.A.Stobberup (2004) Preliminary Ecopath model of the Guinea-Bissau continental shelf ecosystem (NW Africa), p.95-112. *In*: Palomares, M.L.D., D.Pauly, (eds) *West Africa marine ecosystems: models and fisheries impacts.* Fisheries Centre Research Reports 12(7). Fisheries centre, UBC, Vancouver.

Angelini,.R. and M.Petere (1996). The Ecosystem of Broa Reservoir, Sao Paulo State, Brazil, as Described Using ECOPATH. Naga, *ICLARM Q* **19(2)**: 36-41

APHA (1979) American Public Health Association. *Standard Methods For the Examination of Water and Wastewater*, Ed, Greenberg, A.J., A.J. Connors and D.Jerkins., Washington DC. ISBN 0-87553-091-5. 1-1136 pp.

Bverton, R.J.H. and S.J.Holt (1957) A review of methods for estimating mortality rates in exploited fish population, with special reference to sources of bias in catch sampling. *Rapp.P.V.Reun. CIEM*, **140**:67-83

Chrsitensen,V., C.J.Walter and D.Pauly (2004) *Ecopath with Ecosim*: A user's guide. May (2004) Edition. Fisheries Centre, University of British Columbia, Vancouver, Canada, 152pp.

Cottingham, K.L. and D.E.Schindler (2000) Effects of grazer community structure on phytoplankton response to nutrient pulses *Ecology* **81 (1)**: 183-200.

FAO (2002) Food and Agricultural Organization Yearbook. *Fishery Statistics*. Capture Production. **94:**1, Roma, 642p.

Gayanilo, F.C.J., and V. Christensen (1997) *Ecopath with Ecosim model of Aquatic Ecosystem.* ICLARM Annual Report.

Hunter, M.D. and P.W.Price (1992) Playing chutes and ladders: heterogeneity and the relative roles of bottom-up and top-down forces in natural communities. *Ecology* **73 (3)**: 724-732

MacDonald, J. S. and R. H. Green (1983). Redundancy of Variables used to Describe Importance of Prey Species in Fish Diets. *Can. J. Fish. Aquat.*

Mohammed, E.(1980) *A preliminary model for the Lancaster Sound Region.* Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC, Canada.

Okey, T.A. and R.Pugliese (2001) A Preliminary Ecopath Model of the Atlantic Continental Shelf Adjacent to the Southeastern United States. *Moels and Analyses*. Fisheries Centre, University of British Columbia, Canada. **9(4):** 167-181

Palomares, M.L.D and D.Pauly (1989) Predicting the Food Consumption of Fish Populations as Functions of Mortality, Food Type, Morphometrics, Temperature and Salinity. *Marine and Freshwater Research*. **49(5)**: 447-453

Polovina, J. J. (1984a) Model of a coral reef ecosystems I. The ECOPATH Model and its Application to French Frigate Shoals. *Coral Reefs*, **3(1)**:1-11.

Polovina, J. J. (1984b) An overview of the ECOPATH model. *Fishbyte*, **2(2)**:5-7.

Winberg, G.G. (1956) Rate of Metabolism and Food Requirements of Fishes. *In*: Transl. Fish. Res. Board can., Translation series **194**. 253 pp.