Journal of Coastal Development Vol.3, No.1, October 1999: 481-489 ISSN : 1410-5217

A MASS-BALANCE TROPHIC FLOW MODEL AT AWUR BAY IN THE NORTHERN CENTRAL JAVA SEA

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ABSTRACT

A mass-balance trophic flow model is constructed using a simple model termed ECOPATH. The model is applied to an ecosystem at Awur Bay, Jepara, in the Northern Central Java Sea.

The model constructed was built based on twelve components of the ecosystem, which were partitioned into groups of similar species and provide for these species groups, estimates of production biomass, diet and food consumption.

Three trophic level of the components were clearly presented in the model. A number of the estimates mean biomass was 3922.054 gC.m^{-2}.yr^{-1}, while net primary production was 78439.48 gC.m^{-2}.yr^{-1}, over 115 ha area at Awur Bay, northern coast of Central Java.

Keywords : mass-balance trophic flow model, ECOPATH, Awur Bay, Jepara.

I. INTRODUCTION

Quantitative assesment of trophic interactions in a marine ecosystem is a particularly interesting research. It also has important implications for understanding and management of multispecies marine biota as yields as the result of energy flows. Based on the number of species and their yield, the construction of a biomass budget for a box model of an ecosystem is relatively simple and able to provide important information about the ecosystem standing stock and energy flow (Walsh, 1981 ; Pauly, 1982 ; Polovina, 1984 ; Polovina & Ow, 1985 ; Zainuri, 1993).

The Awur Bay, Jepara contains seagrass beds, coral reef and mangrove marine habitats. These three types of habitat are known as nursery areas, providing shelter and food for relatively diverse fish communities (Robertson, 1980 ; Bell & Hamerlin-Vivien, 1982 ; Endrawati, 1992 ; Zainuri, 1993 ; 1994 ; 1996).

Since 1985 several studies and an interdisciplinary research conducted at this region have produced a considerable amount of physical, chemical and biological information. Based on the data collected, a modeling effort to synthesize the information and to identify crucial knowledge gaps should be under-taken.

The objective of this study was to construct a mass-balance trophic flow model of the Awur Bay ecosystem which can be used to broaden understanding of its structure and organization.

II. MATERIAL AND METHODS

The Awur Bay is located on the northern coast of Central Java. The site (110° 37' E, 6° 38' S) extends from 1 40 m deep and covers an area of about 115 ha (Fig. 1).

The trophic ecosystem structure is analysed by applying the Ecopath program. It combines an approach by Polovina (1984, 1985) to estimate the biomass and food consumption of various elements of an aquatic ecosystem with Ulanowicz's (1986) analysis of ecosystem (Christensen and Pauly, 1992).

Twelve compartments were used to built the model. Each compartment represented the biota with a similar role in the food web (plus one box for detritus). Wet mass (g/m2) was used as unit of standing stock and one quarter of a year as unit of time.

2.1. The ECOPATH Model

The model is an analytical procedure to estimate a biomass budget for a box model of an ecosystem given inputs which specify the components of the ecosystem, together with their mortality, diet and energitics value. The possibility to apply several data ressources from the same area which has came from different research result, by converting the data into the same parameter, is the advantage of the model (Christensen & Pauly, 1992). It produces estimates of mean annual biomass, annual biomass production, and annual biomass consumption for each of the user specified species - groups. The species - groups represent aggregations of species with similar diet and life history characteristics and which have a common physical habitat. The model estimates a biomass budget for the marine ecosystem in a static situations under the assumption that the ecosystem is at equiliberium conditions.

Equilibrium conditions are defined to exist when the mean annual biomass for each species - groups does not change from year to year. The condition results in a system of biomass budget equations which, for species - group i, can be expressed as :

> Production of biomass for species i - all predation on species i - nonpredatory biomass mortality for species i - fishery catch for species $i = 0$ for all i.

The ECOPATH model expresses each term in the budget equation as a linear function of the unknown mean annual biomasses (B_i's) so the resulting biomass budget equations become a system of simultaneous equation linear in the B_i's. The mean annual biomass estimates are obtained by solving the system of simultaneous linear equations. The details of the model were presented at Polovina (1984), Polovina & Ow (1985), Pauly (1986), Palomares & Pauly (1989), Christensen (1990), Christensen & Pauly (1992), Zainuri (1993) and Jorgensen (1994).

2.2. System Components

- *Phytoplankton*. Dominated by phytoflagellates together with diatom (Handayani, 1999).
- *Zooplankton*. Consisting of 29 species, which were dominated by *Acartia* sp., *Centro-pages* sp., *Calanus* sp., *Paracalanus* sp., and *Cirriped* nauplius (Zainuri, 1998).
- *Benthic Macroflora*. Dominated by *Thalassia* sp., *Syringodium* sp., *Halimeda* sp., and *Padina* sp.
- *Benthic Macrofauna*. Polychaetes, gastropod, bivalves, echinoids, amphipods and holuthuria.
- *Benthic Fish*. Soleidae, Pleuronectidae (Gloerffelt-Tarp & Kailola, 1998) - *Pipefishes*. Syngnathidae (Gloerffelt-Tarp & Kailola, 1998)

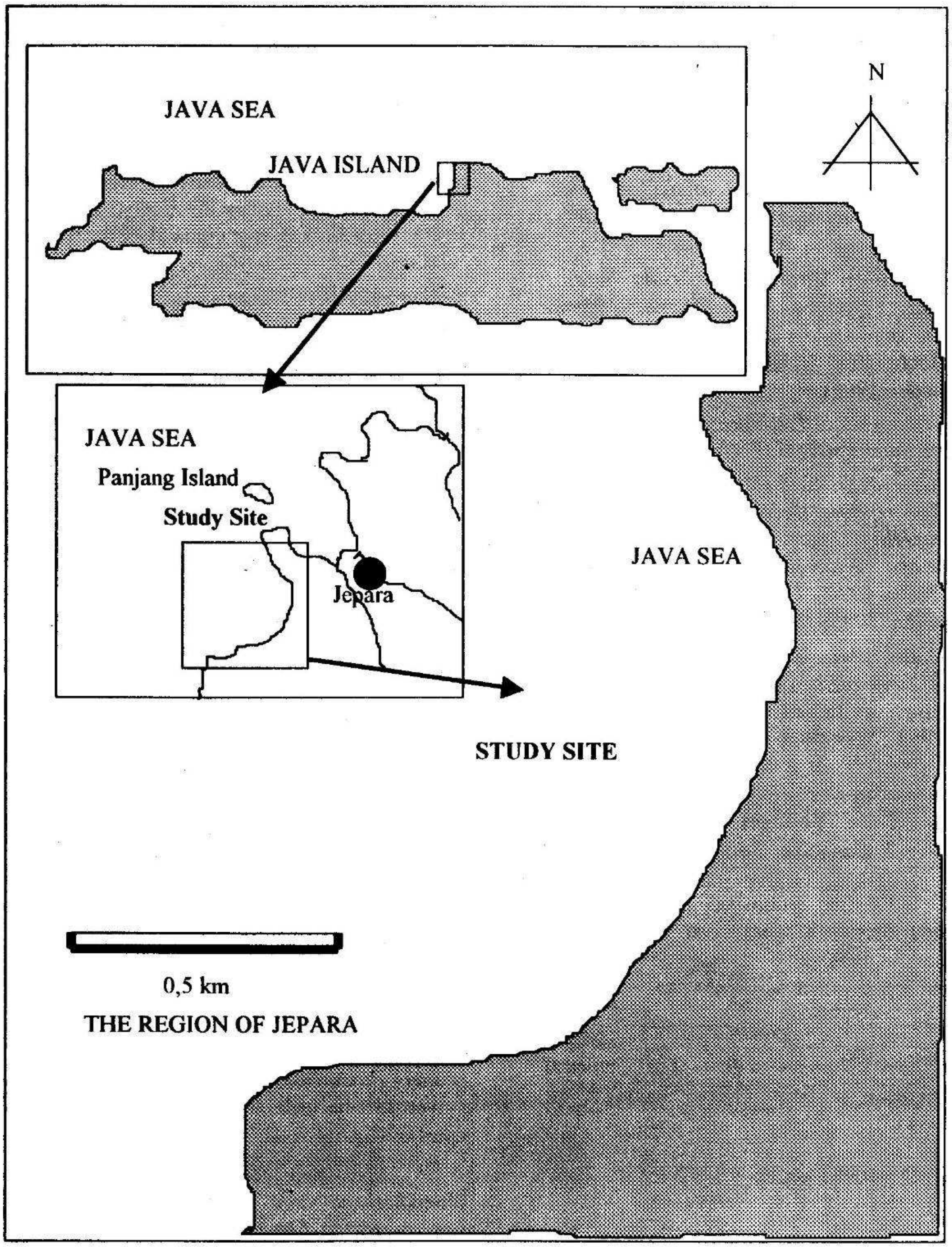

Figure 1. Location of Study Site (110° 37' E, 6° 38' S).

- *Engraulidae*. Anchovies, *Stolephorus indicus, S. devisi, S. waitei, S. Heterolobus, S. batabiensis* (Potier & Boely, 1990 ; 1992 ; Widodo & Burhanuddin, 1995).
- *Leiognathidae*. *Gazza minuta, Leionathus bindus, Leiognathus splendes, Secutor ruconius* (Potier & Boely, 1990 ; 1992 ; Widodo & Burhanuddin, 1995).
- *Clupeidae*. *Sardinella fimbriata, Sardinella gibbosa, Ambligaster sirm, Dussumieia acutallisha spp*. (Potier & Boely, 1990 ; 1992 ; Widodo & Burhanuddin, 1995).
- *Trichiuridae*. *Trichiurus lepturus, Lepturacanthus savala* (Potier & Boely, 1990 ; 1992 ; Widodo & Burhanuddin, 1995).
- *Carangidae*. *Decapterus mcrosoma, D. russelli, Selar crumenopthalmus S. boops, Selaroides leptolepis* (Potier & Boely, 1990 ; 1992 ; Widodo & Burhanuddin, 1995).
- *Scombridae*. *Rastrilliger brachyosoma, R. kanagurta, Scomberomorus llineolatus, S. guttatus* (Potier & Boely, 1990 ; 1992 ; Widodo & Burhanuddin, 1995).

2.3. Data Sources and Parameter Estimation Techniques

Existing published field data and related literature were used as an input values. Personal communication on unpublished values was also used.

Estimates Biomass (B). The empirical relationship is derived from Pauly *et al.* (1993) :

$$\text{Log } D = 0.954 \log Pp + 0.863 \log E - 2.41$$

where :

D = detritus standing stock ($gC.m^{-2}$)
P = primary production (= $gC.m^{-2}.yr^{-1}$)
E = euphotic depth (= 30 m)

Production/Biomass (P/B) Ratios. The average phytoplankton primary production observed in October, 1998 of 0.526 $gC.m^{-2}.day^{-2}$ was used (Handayani, 1999). For the zooplankton, Zainuri (1998) presented daily P/B at 0.3. P/B ratio for the fish species were calculated based on Palomares & Pauly (1989), Potier & Boely, (1990; 1992); Widodo & Burhanuddin (1995).

Consumption / Biomass (Q / B) Ratios. Zooplankton consumption was obtained from Zainuri (1998). While for fish species, estimates were obtained using the data of Potier & Boely (1990 ; 1992); Widodo & Burhanuddin (1995), and the empiric formula from Palomares & Pauly (1989).

Diet Composition. The diet composition was based on Zainuri (1993 ; 1998), Potier & Boely, (1990 ; 1992); Widodo & Burhanuddin (1995).

III. RESULT AND DISCUSSION

The result of mean annual biomass and annual production based on the input values and estimates parameters is presented in Table 1. The diet composition matrix used were presented in the Table2. A flow diagram of a simplified ecosystem food web model of the Awur Bay is schematically given in Figure 2. The estimates mean biomass was 3922.054 $gC.m^{-2}.yr^{-1}$, while net primary production was 78439.48 $gC.m^{-2}.yr^{-1}$, over 115 ha area at Awur Bay, northern coast of Central Java

The three components, Detritus, Phytoplankton and Benthic Macroflora, were present at first trophic level. The other components were at intermediate trophic level (2 - 2.6), while the Scombridae was at the highest level (3).

The flow diagram shows the relationship between the components as a model of prey - predator. The impact of predator can line direct or indirect. Detritus, Phytoplankton and Benthic Macroflora, were dominantly inflow the other components. The greatest inflow from the three component were directed to zooplankton, Engraulidae and Scombridae. The next trophic inflow dominant were line from first trophic level to Clupeidae and Carangidae.

Based of the flow diagram, biomass quantitiy and energy transfer were directly presented and can be compared between one and another component directly or indirectly. The trophic level position also showed the possibility of competition between each component to get their prey, i.e. Clupeidae, Engraulidae, Trichiuridae, Pipefish and Leiognathidae.

Detritus, Phytoplankton and Benthic Macroflora had a positive impact on most other groups. The model estimates that 78435.78 $gC.m^{-2}.yr^{-1}$ of their production is needed to support the other component of the ecosystem. On the basis of the model estimate, the primary production to support the ecosystem, dominated by Detritus, Phytoplankton and Benthic Macroflora, may be due to the seagrass bed, which is known as nutrient trap (Robertson, 1980 ; Bell & Hamerlin-Vivien, 1982 ; 1983 ; Endrawati 1992 ; Zainuri, 1993 ; 1994 ; 1996, 1998). The nutrient availability will be used to support the photosynthesis process of the seagrass and phytoplankton.

The production of Zooplankton and Benthic macrofauna present a number of 3.54 $gC.m^{-2}.yr^{-1}$. It related directly to the the number of zooplankton and benthic macrofauna observed by Zainuri (1998). The presence of zooplankton relate to their herbivorous and detritivorous feeding habit (Bougis, 1974 ; Endrawati, 1992 ; Zainuri, 1993).

The number of species fish present in the estimate model show their *explorative and efficiency of feeding habit* to the food present in the study area. While the prey - predator model between each species can be determined directly which is required another study on the diet composition. The low relative of the internal predation between each of fish species was due to the under assumption of impossibility to determine the migration system of the fishes. Notes by several researchers (Robertson, 1980 ; Bell & Hamerlin-Vivien, 1982 ; Endrawati 1992 ; Zainuri, 1993 ; 1994 ; 1996), showed that the migration type of fishes, especially between two ecosystem, seagrass and coral reef, is a function of light, food and environmental parameters, which made it difficult to estimate their yield.

The estimate model provided a simple sensitivity analysis, which was performed by their input parameter. Several input like the species distribution, the dynamic input based on spatio-temporal and life cycle need to be taken into account for further studies, to make the model more dynamic as an annual mean.

Table 1. Input value and estimated parameters for Ecopath model of Awur Bay ecosystem, in the Northern Java Sea in the end of summer ($gC.m^{-2}.yr^{-1}$)

No	Components	Biomass	P / B	Q / B	EE	GE	Export	Trophic Level
1	Benthic macroflora	3921	20				0	1
2	Phytoplankton	0.526	30		0.6	0.33	0	1
3	Zooplankton	0.093	30	90.9	0.67	0.14	0	2
4	Benthic macrofauna	0.25	3	27.3	0.83	0.15	0	2.3
5	Benthic fish	0.002	0.7	2.8	0	0.25	0	2.3
6	Pipefish	0.002	0.7	2.8	0	0.25	0	2.6
7	Engraulidae	0.15	0.9	3.6	0	0.25	0	2.5
8	Leiognathidae	0.004	0.97	4.85	0.001	0.25	0	2.4
9	Clupeidae	0.006	0.95	4.75	0.001	0.25	0	2.4
10	Trichiuridae	0.006	0.8	4	0	0.2	0	2.6
11	Carangidae	0.013	0.473	2.37	0	0.2	0	2.4
12	Scombridae	0.002	0.01	0.17	0	0.06	0	3

Note : P / B = Production / Biomass E E = Ecotrophic Efficiency
Q / B = Consumption / Biomass G E = Gross Efficiency

Table 2. Diet composition matrix for species groups in the Awur Bay ecosystem, in the Northern Java Sea in the end of summer

No	Components	Predator								
		4	5	6	7	9	10	11	12	Det.
1	Benthic macroflora	1.5	1.5	1.5	0.5	71.5	20.5	0.5	0.5	2
2	Phytoplankton					21	12	25	17	25
3	Zooplankton					29	21	19	22	9
4	Benthic macrofauna					14	26	23	19	18
5	Benthic fish					13	26	23	19	19
6	Pipefish					17	25.5	27	23	7.5
7	Engraulidae					12	43	23	17	5
8	Leiognathidae					14	15	17	19	35
9	Clupeidae					7.5	25	31.5	21	15
10	Trichiuridae							85		15
11	Carangidae									
12	Scombridae									

Note : Det. = Detritus

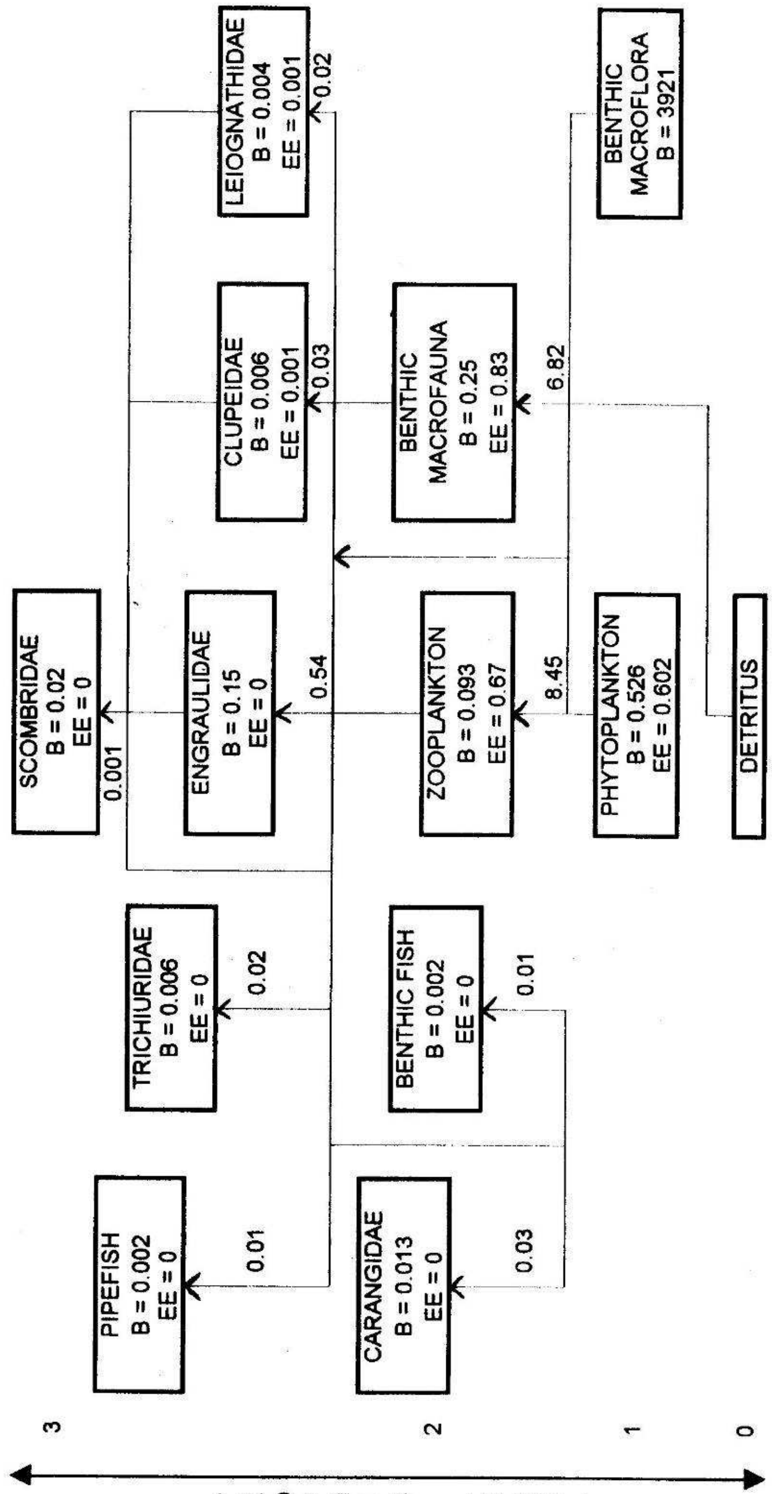

Figure 2. Flow diagram of of Awur Bay ecosystem, in the Northern Java Sea in the end of summer ($gC.m^{-2}.yr^{-1}$)

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