On ECOPATH, *Fishbyte* and Fisheries Management*

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Abstract

A brief account of the origin and basic assumptions of the ECOPATH software and approach is given, with emphasis on their documentation in *Fishbyte*, and to the transition to its successor, the ECOPATH II program. Some implications of the worldwide utilization of ECOPATH II are discussed, along with its supportive use in fisheries management.

Introduction

The Original ECOPATH Model

Given that this is the last issue of *Fishbyte*, it may be appropriate here to give an account of how the development of the ECOPATH model has been followed by *Fishbyte*, and of the present status of this model.

ECOPATH was originally developed by J.J. Polovina from the NMFS South-West Fisheries Center's Honolulu Laboratory as an alternative to the complex data intensive simulation models for ecosystem management that were introduced in the late 1970s. The key idea was to leave out the time dimension, which is crucial in simulation models. Instead it is assumed that the systems under investigation are in steady state or equilibrium, which simply means that input must equal output for the period to be modelled. The ECOPATH model then introduced an analytical procedure for balancing the flows in the system based on estimation of one missing parameter (biomass) for all groups. Thanks to its simplicity, ECOPATH turned out to be more versatile than the data- (and expert-) intensive simulation models. This was enhanced by making the listings (in BASIC, for CP/M computers) and user's instructions widely available (Polovina and Ow 1983).

A large group of potential users, the members of ICLARM's Network of Tropical Fisheries Scientists and, more generally, the *Fishbyte* readership first read about ECOPATH in an editorial by John Munro in the April 1984 issue. Under the headline "ECOPATH - the first of a generation", he introduced the new ECOPATH software as "the big news for this issue". John Munro saw the new model as one that undoubtedly would spur the development of a new generation of ecosystem models, and as time would show, he was right. Crucial here was that the input data (mainly mortality rates, food consumption rates, and diet compositions) required for steady-state models have already been estimated and published for many groups and systems, and that ECOPATH offers an efficient way of exploring these data, and of deriving a possible solution for how the systems may be balanced.

In the following issue of *Fishbyte*, Polovina (1984a) gave an overview of the ECOPATH model, later supplemented with program corrections (Polovina 1986). He originally applied the model to a coral reef, the French Frigate Shoals, Hawaii (Polovina 1984b), where data had been gathered for most of the groups in the system, as part of a larger project, but where no one had tried to put them together to give an overall description of the ecosystem. J.J. Polovina put the pieces together, and showed that his model could balance the system by calculating the missing biomasses. Moreover, the production estimates he derived turned out to be similar to the results of field experiments (Grigg et al. 1984).

In the following years the ECOPATH software was widely distributed, but not many applications appear to have found their way into the scientific literature. Yet, the potentials of the model remained obvious. This could be judged, e.g., from one of the few applications, the outcome of a study visit by two Malaysian NTFS members to ICLARM HQ. Their work, funded by the International Development Research Centre (Canada) and supervised by D. Pauly resulted in an ECOPATH model of a tropical shallow-water area off Terengganu on the east coast of Malaysia (Liew and Chan 1987). A slightly modified version of this model is shown in Fig. 1.
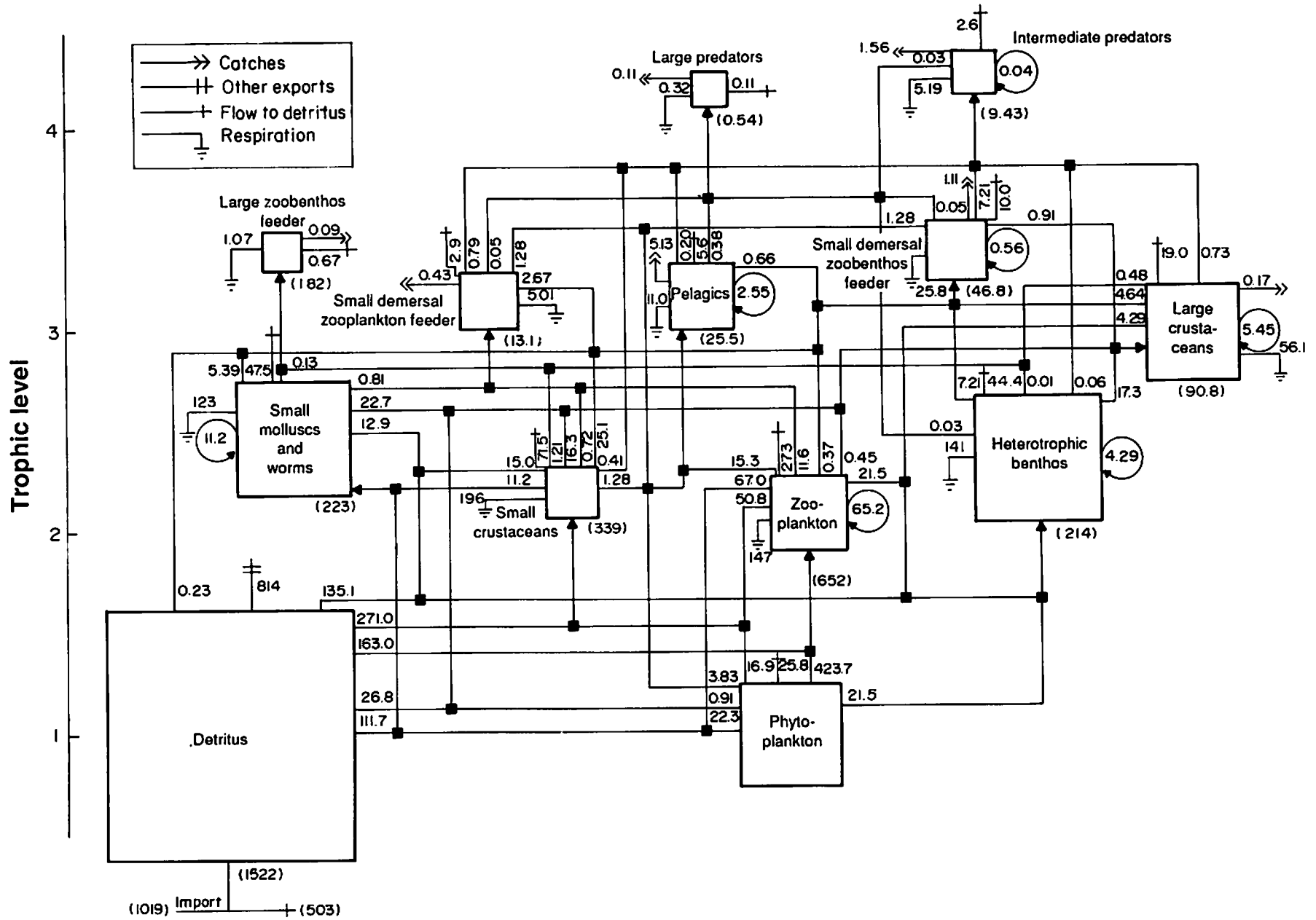

Fig. 1. Mean annual trophic flows in the Kuala Terengganu inshore ecosystem, east coast of Peninsular Malaysia, modified from Liew and Chan (1987) as follows: 1) The reported biomass for small demersal zoobenthos feeders (0.45 t·km²) was considered too low, probably due to sampling bias, and is not used. 2) Consumption for intermediate predators was lower than production; here consumption is assumed to be 4 times production. 3) Production/consumption ratio for small demersal zoobenthos feeders was too low: this ratio is here assumed to be 1/4.

ECOPATH then received a second lease of life when Daniel Pauly, Mina Soriano and Maria Lourdes "Deng" Palomares prepared for presentation, at a conference in Kuwait, a paper on "Improved construction, parametrization and interpretation of steady-state ecosystem models". In this paper, presented in December 1987[a], the concept of the ECOPATH model was developed further, and the foundation laid for what we now call ECOPATH II (with J. Polovina's agreement). This development included, among other things, the incorporation into the ECOPATH approach of the theory of network flow analysis developed by Ulanowicz (1986), which was seen as potentially useful for system characterization and to enable comparisons between different ecosystems.

In its basic structure, ECOPATH II is identical to the original ECOPATH model, the main differences being user-friendliness and the fact that ECOPATH II allows a large array of input data to be unknown, not just the biomasses. Also, successive versions of ECOPATH II incorporated a widening array of diagnostics for their characterization of ecosystems and their component groups (Christensen and Pauly 1991, in press a).

In most recent years the development of the ECOPATH II approach has moved at a faster pace, mainly due to substantial funding from the Danish International Development Agency (DANIDA), for a project at ICLARM HQ on "Global comparisons of aquatic ecosystems". A major component of this project, run by the author, is the further development and dissemination of the ECOPATH II software.

The contribution from the International Council for Exploration of the Seas (ICES), should also be acknowledged. ICES through Mr. J. Pope of Lowestoft Laboratory, invited Daniel Pauly and the author to convene a poster theme session on "Trophic models of aquatic ecosystems" at its Statutory Meeting in Copenhagen, October 1990. One result of the session was some 36 contributions from all over the world, many of which were by authors from developing countries. Ecosystems as diverse as Chinese silkworm-fishpond cultures, Mexican lagoons, African lakes, and ocean systems were presented. Noteworthy was also that a very large proportion of the contributions had been prepared with the ECOPATH II software.

Most of the contributions to this ICES Theme Session are about to be published, together with invited contributions, in an edited volume on "Trophic models of aquatic ecosystems" (Christensen and Pauly, in press b). This book will include descriptions and quantified models of around 40 aquatic ecosystems. Some have been contributed by very experienced ecosystem modelers. However these are vastly outnumbered by contributions from scientists who have never before published anything like an ecosystem model. It is very encouraging that there are so many colleagues ready to take the steps from assembling and standardizing data on a single-species basis, to gathering all available data on trophic interactions in a given area and analyzing these in a quantitative context.

We also see this as confirming the views brought forward by Munro and Holdgate (1991) in a recent publication presenting the IUCN/UNEP/WWF Strategy for Sustainable Living, which endorses ICLARM's work in this area, and which states that "the focus of management (of marine resources) should be shifted toward entire ecosystems, using experience gained in the management of single stocks as well as other information. Also, this states that while "lower-income" regions may not have the scientific and technical resources for this approach [...] many management problems cannot wait for the outcome of ambitious research programmes".

ECOPATH II and Fisheries Management

ECOPATH II may at a first glance not seem very useful for fisheries management. One must however remember that, for many systems, the data for more complex models are simply not available, not to speak of the expertise and experience to develop and interpret the more complex simulation models. However, with a relatively simple (steady-state) description of a system, one can assure oneself that the available data from that system are all used and put in a context where comparison with other data is an inherent part of the analysis.

An example of this can be given for the Kuala Terengganu ecosystem presented in Fig. 1. Based on the flows in this model, and on the theory of Leontief (1951), the direct and indirect trophic effects any of the groups has on all other groups in the system can be quantified (Christensen and Pauly 1991; in press a). This is shown on Fig. 2, from which it can be concluded, among other things:

1. That the fishery has a strong negative impact (-0.25) on the intermediate predators, while these only have a minor impact on the fishery (.09).

2. That the fishery has a positive, if indirect impact on the small demersal zoobenthos feeders (.05) due to removal of predators on this group.

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[a]Editor's note: this paper, of which I had received and returned page proofs was just about to go to press when Kuwait was invaded, in August 1991!
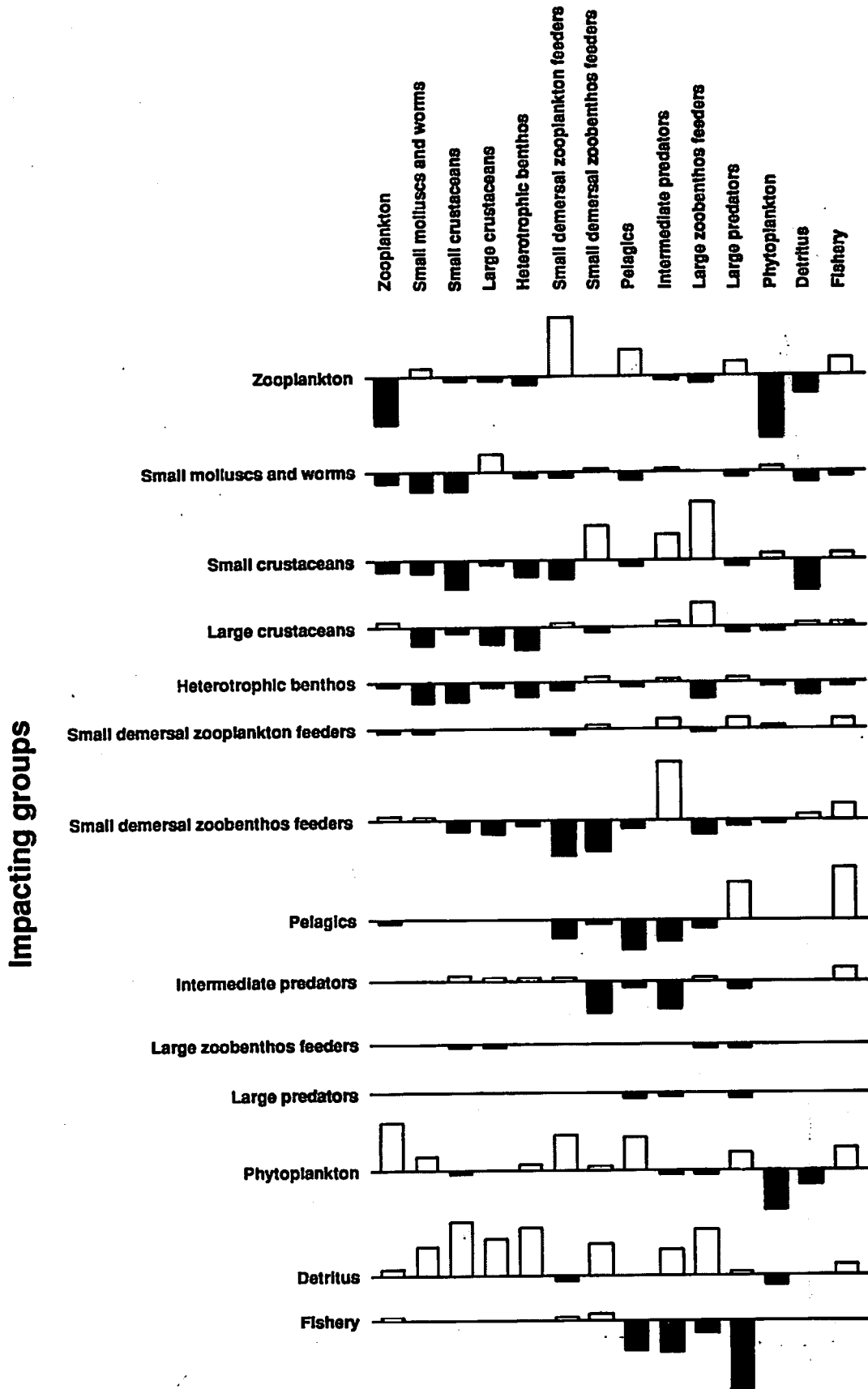
Impacted groups

Fig. 2. Mixed trophic impacts for the Kuala Terengganu inshore ecosystem, expressing the direct and indirect impacts of the groups given at the left; positive impacts are shown above the baseline; negative below. The impacts are relative, but comparable between groups.

3. That none of the groups has a negative impact on the fishery. It can be concluded that in the case considered here, the negative impact from the large predators due to predation on other fished groups is counterbalanced by the positive impact due to catches of large predators. It is thus not likely that much can be gained from increasing the fishing pressure on the apex predators.

4. That the impact from large zoobenthos feeders on any other group (10th row with bars) is negligible. One interpretation of this is not to allocate too much effort in improved estimation of parameter for this group, which hardly matters. It is better to concentrate on other groups.

One important aspect of ECOPATH is also that analyses based thereon reveal gaps in the present knowledge. At the same time the use of a common "language" facilitates comparisons between systems and experiences from one area become more easily transferable to another.

One must also ask: does fisheries management really make sense if one does not have an idea of the biomass and flows of the major groups in the system that is to be managed? Certainly not: we know now that the complex tropical fisheries which are our main concern cannot be managed on a single-species basis (Pauly and Christensen, in press). Of course ECOPATH II, as a steady-state model, does not offer any approach - beyond perhaps the "trophic impacts" presented above - to predict changes due to different harvest strategies, etc. Therefore, and in view of the fact that this form of analysis is badly needed for tropical fisheries, we intend to develop, in the coming two years, models specifically tailored for answering "what if" questions. These will share one key feature with ECOPATH, however: they will describe the whole ecosystem, not just its exploited part. It is our experience from working with a large number of ecosystem models that this "system view" has two immediate benefits when examining the flows in a system: 1) linking predators and preys imposes a powerful constraint on the consumption by predators (and hence their production and catches) which must relate to the production of prey; and 2) the efficiencies of energy transfer in the systems must conform to established relationships between primary production, fishing pattern and potential catches.

The development of these new models does not mean that the development of ECOPATH II will be discontinued. Indeed, a new version (2.1) of ECOPATH II has just been released, and a version with major additions is being prepared for release in about a year from now. Interested readers may wish to contact the author for further information.

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