Insights into the Ecological Performance of Agroecosystems with ECOPATH II

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Aquatic and terrestrial ecosystems have many commonalities. The steady-state mass-balance model concept and basic ecological principles upon which ECOPATH II is founded (see Christensen and Pauly, p. 34) were developed for aquatic ecosystems but can also be applied to terrestrial systems.

This modeling software has already been applied to hypothetical and real agroecological systems. The analytical prospects look promising. Lightfoot et al. (1993) used it to compare ricefield scenarios with and without fish, and tentatively concluded that the integration of fish might lead to higher efficiency of nutrient use in rice production, and that some of the adverse effects of intensified rice monocropping, on soil microbial biomass and soil quality over the long term, might be mitigated through the inclusion of fish.

Since then, the scope of descriptive agroecosystem modeling and analysis with ECOPATH II has expanded horizontally and vertically: horizontally, as models have broadened to include farm enterprises besides rice and fish, and as examples are drawn increasingly from farms rather than from on-station research (e.g., Ruddle and Christensen 1993; van Dam et al. 1993; Dalsgaard et al. 1995); and vertically, in the sense that models have been developed at different hierarchical levels (Fig. 1). Whereas initial analyses focused on detailed trophic interactions at the farm subsystem level (Fig. 1A), models are now being generated at the whole farm level (Fig. 1B) in order to investigate aggregate farm system properties.

Delineation of an agroecosystem, however, does not end at the farm level. In the same way that ricefields and fishponds are 'nested' within farms, so farms can be viewed as being nested within communities (Fig. 1C), communities within watersheds, and so forth. This raises the prospect of applying mass-balance modeling concepts and tools at multiple and perhaps complementary levels within a hierarchical agroecological framework.

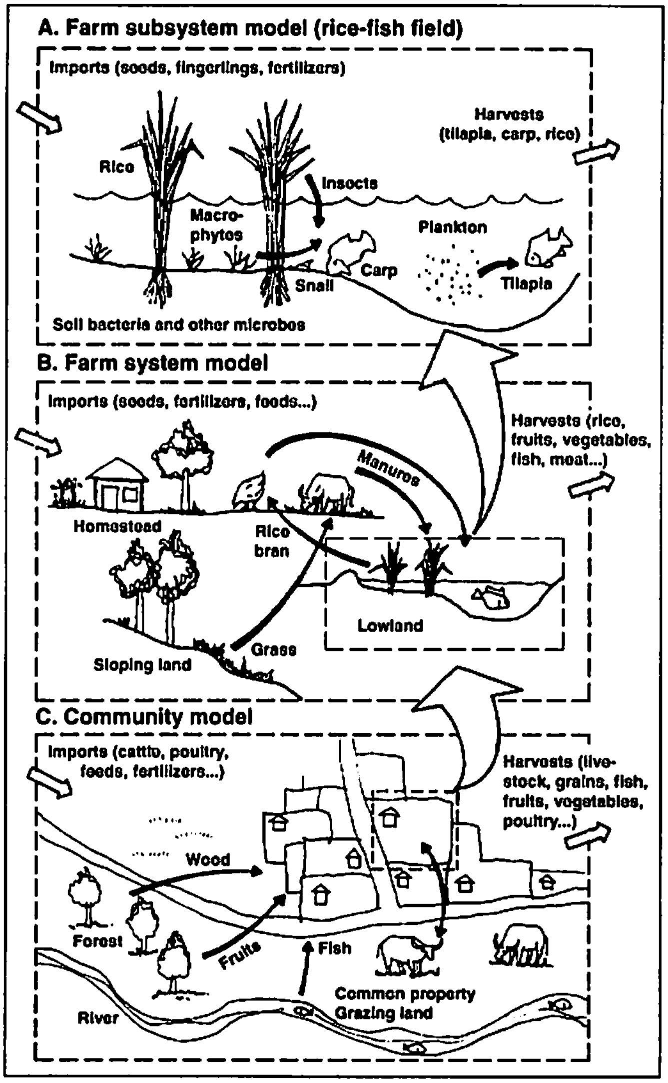

Fig. 1. A hierarchical framework for steady-state agroecological analysis (stocks and flows are quantified).

ECOPATH II also offers insights into the maturity of aquatic ecosystems (Christensen 1995) and it is anticipated that mass-balance modeling and comparison of agroecosystems will provide quantitative insights into the ecological performance and sustainability of farming (Lightfoot et al. 1993; Dalsgaard et al. 1995). Aggregate properties such as diversity, nutrient cycling, nutrient efficiency, productive capacity, standing biomass, efficiency and productivity (yield) are expected to differ according to a system's state and performance (Dalsgaard 1995). Several of these attributes can be computed directly using ECOPATH II. Others may be determined through supplementary analyses.

The number and quality of models generated are ultimately determined by the availability of quality data. Only few data-intensive studies have been conducted within a steady-state system mode, as depicted in Figs. 1A and B. To the authors' knowledge, no comparative studies have been carried out at levels above that of the individual farm. Agricultural research has, in the past, by and large focused on individual farm components, ignoring their interactions with most of the surrounding agroecosystem. There are, however, strong indications that systems-oriented research will receive much more attention in the future. Agroecological analysis, natural resources management, integrated agriculture-aquaculture and agroforestry are approaches which all testify to a gradual reorientation in international agricultural research.

Further Reading

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Ruddle, K. and V. Christensen. 1993. An energy flow model of mulberry dike-carp pond farming system of the Zhujiang Delta, Guangdong Province, China, p. 48-55. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390 p.

van Dam, A.A., F.J.K.T. Chikafumbwa, D.M. Jamu and B.A. Costa-Pierce. 1993. Trophic interactions in a napier grass (*Pennisetum purpureum*)-fed aquaculture pond p. 65-68. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390 p.

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Editor's note: ICLARM Conf. Proc. 26 (Trophic Models of Aquatic Ecosystems), edited by Villy Christensen and Daniel Pauly (1993) is a useful compendium of applications of ECOPATH II across large- and small-scale ecosystems. It contains 50 papers on ecosystems ranging from ricefields to oceans. This book is available from ICLARM at US$15 (surface mail) and $32 (airmail).

ICLARM Contribution No. 1178.

Experimental Culture of *Acartia plumosa*:

A Copepod for Use in Marine Fish Hatcheries

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Introduction

Marine copepods (*Acartia* spp.) are being promoted as a food organism in some marine hatcheries. They used to be collected from the wild, as plankton, and fed to marine fish postlarvae, as alternatives or supplements to *Artemia nauplii.* Substitution of an *Artemia* diet with wild copepods has often improved the growth and survival of grouper (*Epinephelus fuscoguttatus*) larvae (Slamet and Diani 1993). However, collecting plankton takes a long time, and the availability of the required species and quantities are never sure. Continuous culture of such copepods might provide a stable supply.

Acartia spp. are rich in highly unsaturated fatty acids, especially eicosapentaenoic acid and docosahexaenoic acid (Watanabe et al. 1983). Moreover, they provide a wide size range of food organisms for hatchery use (six naupliar stages and six copepodid stages). Unlike some other copepods that carry egg sacs (e.g., *Pseudocalanus, Pseudodiaptomus* and *Oitona* spp.), the eggs of *Acartia* spp. sink to the bottom of culture tanks and are easily separated from adult populations by siphoning.

The taxonomy of *Acartia* spp. has been well studied (e.g., Mori 1940; Ito 1956; Abraham 1970; Greenwood 1972; Ueda and Hiromi 1987) and mass culture of *Acartia* spp. has been described (e.g., Stottrup et al. 1986; Ohno and Okamura 1988; Ohno et al. 1990). Sunyoto (1991) identified two species in West Java: *Acartia pasifica* and *A. plumosa*. The former was dominant in the open sea and the latter in a seawater pond. The Bojonegara Research Station for Coastal Aquaculture, West Java, used to collect these species for rearing marine fish larvae of seabass (*Lates calcarifer*), grouper (*E. fuscoguttatus*), but there are no reports from Indonesia of attempts to culture copepods for this purpose. We assumed that *A. plumosa* would be the more suitable species for use in hatcheries because it tolerates a wide range of salinities: from brackishwaters up to about 55 ppt.

Experimental Culture

Comparative Feeding Trials

A. plumosa adults were collected from a seawater pond (salinity, 50 ppt), transferred to 100-l seawater tanks (salinity, 34 ppt) with gentle aeration, and were fed with *Chlorella* and *Tetraselmis*. All work was done at 26-29°C. For a preliminary trial one day later, batches of adults were stocked in nine 3-l glass flasks at 9,000 per flask. There were three replicated feeding treatments: 1) *Chlorella/ Nannochloropsis* (2-6 μm); 2) *Tetraselmis* (8-14 μm); 3) baker's yeast (3-6 μm). The daily amounts fed per flask were 200-400 x 10^7 for *Chlorella*, 200-400 x 10^5 for *Tetraselmis* and 0.03 g for baker's yeast. The bottom water in the flasks was siphoned out every day. The experiment was terminated after nine days and surviving *Acartia* counted. The survival was 17 to 23% (mean 18%) for treatment 2 (*Tetraselmis*) and zero to 0.1% for the other feeds.