Fish Production, Catches and the Carrying Capacity of the World Oceans

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Abstract

A brief review of the status of the world fisheries is presented with emphasis on the differences between catches, (= landings + bycatch), biological production of fish, and predation (= production - catches). The ECOPATH II approach, implemented as a new, Windows-based software is then shown to allow construction of a stratified world model accounting for global catches, production of and predation on fishes, and thus improved estimates of global potentials. A newly initiated, cooperative project is described through which the foundation for such a global model could be constructed, based on a stratified database with more than 100 trophic models. Collaborators are invited to join in this, and will be assisted in constructing models covering their areas of interest.

Introduction

Fish production, catches ... Wait! Isn't that the same? For biologist, it's not; but the terms are often used as synonyms since the processing industry turns catches into fish products. Our interest here, however, is in the processes in the sea: how much we extract (= the catches), and how much is actually produced, and then consumed by predators, which thus compete with the fisheries.

One of the earliest expressions of the relationship between production and catches in fully exploited stock is by Graham and Edwards (1962) who guessed that "properly harvested, it is reasonable to suggest that [fish stocks] may yield 50% by weight, at least, of the net annual production".

Ryther (1969) used this 50% figure as well, albeit implicitly, but it is in the form of "Gulland's equation" for estimation of potential yield that Graham and Edwards' 50% guess became most famous. The equation (actually proposed by Alverson and Pereyra 1969) states that

Potential yield = 0.5 \cdot B_o

where B_o is the unexploited biomass, and M is assumed equal to optimum fishing mortality, i.e., to the level of fishing generating the fabled Maximum Sustainable Yield (F_{MSY}).
Members Write

Mr. B. Ahilan, Assistant Professor, Department of Fisheries Extension, Fisheries College, Tamil Nadu Veterinary and Animal Sciences University, Tuticorin 628 008, India.

I am doing a Ph.D. program in Fisheries Science (area of specialization in aquaculture).

I have taken up research work in the maturation and breeding of goldfish Carassius auratus. For this purpose, I require literature and related information on maturation, induced breeding and growth of goldfish. Hence, I request you to kindly send me relevant literature.

This will be of immense use for me to pursue my research program. I will be grateful to you for this favor. Thanking you with kind regards.

Thesis Abstracts

Modelling Studies of Fish Production in Integrated Agriculture-Aquaculture Systems*

ANNE A. VAN DAM

The general objective of this thesis is to formulate a general model for fish production in integrated ponds and ricefields as a means of obtaining a better understanding of these production systems. Integrated culture systems produce fish without large industrial energy inputs and have positive effects on the whole farm system. A main characteristic is their environmental variability, notably dissolved oxygen concentration and temperature. A systems approach using mathematical models is advocated because it can lead to insights that have universal applicability while avoiding the pitfalls of site- and species-specific, expensive experimental work. Two modelling approaches are distinguished: descriptive models, generally the result of statistical analysis of datasets; and explanatory models, based on knowledge of the biological processes underlying fish production.

Multiple regression analysis (a descriptive modelling technique) was used for the analysis of data from 15 integrated rice-fish production experiments with the Nile tilapia (Oreochromis niloticus L.) in the Philippines. Results showed that this technique led to insights that had not been obtained through separate analysis of the experiments. The main drawback of this method was that the models were not applicable to other production environments.

An explanatory model (called Fish Growth Simulator, or FGS) for growth of O. niloticus was developed on the basis of an existing simulation model for the African catfish Clarias gariepinus Burchell (1822). After parameterization and calibration, the model gave good predictions of fish growth in independent datasets. Parameterization and calibration of the same model for the rainbow trout Oncorhynchus mykiss (Walbaum) demonstrated the generality of the model and it was concluded that, provided that enough data are available, the model may be used to predict growth in a wide range of fish species. Food amount and composition, and temperature were the environmental variables upon which the model based its predictions.

FGS was expanded with a dissolved oxygen module to accommodate oxygen as an environmental variable. The module was based on the hypothesis that oxygen is needed in sufficient amounts for aerobic metabolism, and that gill surface area limits the supply of oxygen to fish. The resulting model allowed the simulation of fish growth under low dissolved oxygen concentration and also provided an explanation for differences in the final weight of fishes, both within and between species.

FGS was used for simulation of food and oxygen limitations in waste-fed fishponds in Honduras, Thailand and Rwanda. The model simulated fish growth for various combinations of environmental conditions: temperature, food availability and dissolved oxygen concentration. Validation, using data from Indonesia and Panama, was not successful because estimates of the food consumption rate in these countries were not reliable.

Methodology, the role of oxygen in fish metabolism and growth, implications of the models for the management of integrated agriculture-aquaculture systems and further work are also discussed.

* Accepted on 10 May 1995 for a Ph.D. degree in Agricultural and Environmental Science at the Wageningen Agricultural University, Wageningen, The Netherlands. Dr. A.A.v. Dam's current address is: Department of Fish Culture and Fisheries, Wageningen Agricultural University, PO Box 338, 6700 AH Wageningen, The Netherlands.

On the Nutritional and Reproductive Cycles of Mullets, Liza dussumieri (Val.) and Mugil cephalus L. of Muthupet Saline Swamp, Tamil Nadu in the Context of Aquaculture*

P.R. BASKARAN

A comparison of the biology of the two mullet species inhabiting the Muthupet saline swamp illustrates the concept of niche segregation; not only the spatial and functional aiche but also the hypervolume or multidimensional aiche. Liza dussumieri is the smaller fish and Mugil cephalus is relatively large. The life span of L. dussumieri has been calculated to be three years whereas that of M. cephalus is four years. Males were more dominant than females in both species. L. dussumieri was found to be a semi-annual breeder, with the breeding season extending from August to September and December to February. M. cephalus was found to breed during the post monsoon period (January to February/March) with an annual cycle. L. dussumieri appears to reach sexual maturity at a relatively small size and lesser age than M. cephalus. Both species eat mainly vegetable matter. L. dussumieri had a high level of feeding intensity once a year plus a moderate feeding intensity at another time of the year. M. cephalus had several fortnights of intense feeding, with other moderate feeding levels throughout the year and breaks in between. In L. dussumieri muscles appeared to function as the storage organ more than the liver, but in M. cephalus for the buildup of the gonads, the liver seemed to contribute more than the muscles. Environmental parameters are said to influence events in reproductive and nutritional cycles and the fishes themselves choose a suitable period for reproduction by intrinsic mechanisms so that the new generation encounters a suitable environment.

Congratulations to Dr. Anne Van Dam

Dr. Anne van Dam, who has worked with ICLARM and its collaborators in Malawi and the Philippines, successfully defended his thesis on May 10th. He was also awarded the Wageningen Institute of Animal Sciences Ph.D. Students Publication Prize for his paper "Simulation of the effects of oxygen on food consumption and growth of Nile tilapia", co-authored with Dr. Daniel Pauly and now in press in Aquaculture Research Volume 26, 1995. The Abstract of Anne's thesis is given on p. 33 along with his current address in the Netherlands.

Erratum

Jimmiel J. Mandima, author of the article "Socioeconomic Factors that Influence the Adoption of Small Scale Rural Fish Farming at Household Level in Zimbabwe", published in Naga, the ICLARM Quarterly 18(2):25-29 (April 1995), is a Research Fellow at the University Lake Kariba Research Station, University of Zimbabwe, PO Box 48, Kariba, Zimbabwe. Our apologies to the author for inadvertently missing out his affiliation and address.
Given that biological production can be defined as $P = Z \cdot B$ (Allen 1971) and that $Z = M + F$, setting $F_{MST} = M$ implies the 50% rule.

The evolution of this and similar guesses are reviewed in Pauly (in press); Fig. 1 shows some of the estimates of global potential catch obtained using these guesses.

![Graph showing global marine catches, 1948-1993](image)

**Fig. 1.** Global marine catches, 1948-1993. To account for discarded bycatch, the estimate 27•10^6 t year^-1 of Altverson et al. (1994) was applied to 1992, and prorated to the total catch of all other years. The full dots show some estimates of potential world catch, and the year they were published (from Table 1 in Pauly, in press). Note that none of these estimates explicitly considered the magnitude of the bycatch problem. The insert shows the % rate of change of the series, smoothed over three years (adapted from FAO Yearbooks).

Fisheries catches, which have grown in leaps and bounds since WWII or more precisely by around 4-8% per year in the 1950s and 1960s, have been stagnating since the late 1980s, even though 1993 (the last year for which global figures from the Food and Agriculture Organization of the United Nations are available) with catches and aquaculture production slightly in excess of 100 million tonnes, was the largest ever.

FAO has well documented the extent to which present fishing practices are unsustainable, emphasizing, e.g., that the overwhelming majority of the stocks it monitors are either overfished, or recovering from previous overfishing (Garcia and Newton, in press). Other global studies have estimated the discarded bycatch of fisheries, presently a staggering 27 million tonnes per year (Fig. 2), and the extent of economic losses experienced by the world fisheries — over US$ 50 billion per year, largely met by subsidies.

No competent observer believes that this situation can last, and indeed, international efforts are now being made to radically change the ways of our fisheries, and to put them on an economically and biologically sustainable basis.

The second of these aims - and perhaps some of the first - will have to involve ecosystem consideration: the stocks the fisheries exploit are parts of ecosystems, most resource species feed on one another, and sustainable fisheries must account for this. Fisheries scientists have been reluctant to consider such ecosystem interactions in the past: it did not seem necessary, and it was dubious if it could be done anyway — especially if one has to invest several years’ worth of one’s time to construct and validate even a single-species simulation model (see Hertlein, this issue for a recent example).

This perception of the situation has changed: fisheries scientists, throughout the world now largely agree that they must find ways to account for species interactions - even when they still perform single-species assessments. Several generic approaches for multispecies analysis have therefore recently emerged. One of these is multispecies virtual population analysis (see below); another simpler approach is the construction of mass-balance, trophic models, developed by the authors on the basis of earlier work by J.J. Polovina and co-workers at the National Marine Fisheries Service laboratory, Honolulu, and presented as the ECOPATH II approach and software, in an earlier issue of Naga (Christensen and Pauly 1991).

We will briefly review major features of this approach, then move to the presentation of a new release of the software incorporating it, and whose features turn ECOPATH II (version 3.0) into an almost completely new approach (Box 1). We then present a recently initiated project through which we plan to construct a stratified database of trophic interactions, production, and abundance in the world oceans, based on 100+ ECOPATH II models constructed in collaboration with, and/or by colleagues worldwide.

**The Modeling Approach and Some Key Results**

The construction of an ECOPATH-type ecosystem model relies on the truism that, for any producer (e.g., a given fish stock) and time period (e.g., a year or season)

Production = fisheries catch + predation mortality + other mortality + biomass accumulation + loss to adjacent systems

In addition, the groups in the system are linked through predators consuming prey. Such consumption can be described by

Consumption = Production + non-assimilated food + respiration.

This implication of the two relationships is that the model is mass-balanced, i.e., mass is "conserved", or accounted for. Call it as we may, this principle provides an extraordinary rigid framework — formalized using a system of linear equations — through which the biomass of different consumer groups within an ecosystem can be estimated, along with the trophic fluxes among them (Fig. 2).

Important here is that the information required to complete an ECOPATH II model is of the very type routinely collected by fisheries scientists, (e.g., catches) or estimated in the context of single-
Box 1. Announcing the release of ECOPATH II Ver. 3.0.

ECOPATH II (Ver. 3.0) is now ready for release. The new version includes the following novelties, among others:

*The Windows-platform:* The 'old' ECOPATH II was programmed in Microsoft Professional Basic, and was (and still is) a versatile program with the major advantage that it can be run on basically any PC using DOS. The old version further has the advantage that it is very simple to use for newcomers, as there is a 'natural path' for the user to walk through the routines. In contrast the new version, programmed in Microsoft Visual Basic, and which has the flexibility (spreadsheet input forms, multiple open windows, etc.), and consequently also the complexity of Windows programs is much more powerful, but it also takes more effort on the user's part to use these facilities. We wish to offer the advantages of both the DOS and the Windows platform; thus we will continue to support the DOS version (2.2+) of ECOPATH II; the DOS and Windows versions can share data files.

*The graphics:* Up to now, ECOPATH II has had very limited graphing facilities, and it was up to the user to produce graphs for presentations. A major new improvement in the new version is an interactive method for construction of the flowchart, i.e., of the main output of ECOPATH II. Such flowcharts contain a wealth of information, and it is complicated and time-consuming to prepare them manually. It has not been easy to program the flowchart routine, however, due to the complexity associated with arranging up to 50 groups with connecting flows, labels, etc. Indeed this complexity is the main reason why it has taken us two years to release the new version of ECOPATH II.

Another, simpler, but also very versatile, and information-rich new feature is the mixed trophic impact graph. This gives an overview of how each of the groups in the system impacts each other through both direct and indirect trophic interactions. A number of additional graphs are included (notably for comparing trophic "pyramids"), and more will follow in coming versions.

*EcoWrite:* In the new version it is possible to enter a remark for each input parameter at the press of a button. Such remarks may indicate the sources of estimates, describe how they were standardized, etc. Once the model is constructed, a reporting facility extracts the remarks, and opens a built-in word processor. The text may then be edited or saved in a form accessible from virtually any other Windows-based word processor.

*Empire:* Often system-specific estimates of input parameters are not available for all groups to be included in a model. In such cases it can be useful to use one of the many published empirical relationships (e.g., in Calder 1984), especially where there are physiological constraints likely to overrule local conditions, e.g., in the case of the consumption/biomass ratio of fish (see Pauly 1989). To facilitate parametrization, we describe a number of these relationships in a new, interactive routine ("Empire"). We intend to add relationships in each succeeding version, and we encourage readers to contact us if they know of relationships we should consider including.

Fig. 2. Mass-balance model of the coastal fisheries resources of Brunei Darussalam, constructed using the ECOPATH II approach and software (from Silvestre et al. 1993).
species studies (biomasses, mortality rates, diet composition, etc.), along with biological information on the nonharvested components of the ecosystems — as usually studied by marine biologists.

Thus, at least these two disciplines are brought together every time an ECOGRAPH II model is constructed, and a large amount of scattered information is standardized, and rendered mutually compatible that would otherwise have languished in scattered journals, reports and filing cabinets. Box 2 presents a new approach through which this process has been made statistically more rigorous than previously.

So far, nearly 50 systems of marine and estuarine ecosystems have been published (see Box 3 for freshwater and terrestrial systems), authored by over 70 scientists (Fig. 3). Moreover, these models have not only summarized a large amount of data for the systems they represent, but jointly, they have allowed for powerful generalizations to emerge.

One of these is that the transfer efficiency of biomass between trophic levels in aquatic ecosystems, though highly variable, tends to have a mean value of 10%, as long suspected, but never before demonstrated conclusively (Fig. 4).

Another generalization is that the fraction of fish production consumed by other fishes, is even within strongly exploited systems, much larger than the catches, hence invalidating the guesses which led to Gulland’s equation (see above, and Pauly, in press).

Yet another generalization is that the primary production required to sustain the world fisheries is far higher than previously anticipated, itself suggesting broad limits to the carrying capacity of the world’s oceans (Box 4).

We consider these results, and other insights gained through the systematic application of the ECOGRAPH II approach to various ecosystems.
to amply justify our present effort to construct a global model of trophic interactions in the world ocean. The road we are taking can be briefly described as follows: we will use the existing stratification of the world oceans of Longhurst et al. (1995) to identify 50-60 large marine ecosystems (LMEs); within each of these we will make a detailed stratification based on water depth, and resource system type. Based on the systems to which they apply, published ECOPATH II models will be assigned to LMEs and substrata, and then raised to LMEs, oceans, resource system types, and to the world level.

For some groups ECOPATH II models do not provide sufficient constraints to limit the possible parameter ranges. This is particularly true for important consumers with low fishing and predation mortalities, such as marine mammal and mesopelagic fishes. For such groups, independent information is of special interest, and as an example we collaborate with marine mammal specialists at the Fisheries Centre, University of British Columbia, Canada, to evaluate the global trophic impact of marine mammals.

**Required Steps and Expected Insights**

For a global model to be more than the sum of its parts, its components (i.e., the models representing LMEs) must have been derived independently of each other. Only then will overestimates in some models be compensated - at least in part - by underestimates in some other models.

Thus our emphasis on assisting collaborators in publishing their models, based on independent, locally available datasets rather than for us to attempt constructing all required models, based on widely available datasets and publications.

However, we do not perceive our collaborators as providers of local models, while we reserve ourselves the privilege of generating the global syntheses. Rather, all collaborators will be given sets of all ECOPATH II files generated by all other collaborators, so that they may generate their own syntheses of the data.

The completion of the world model will require as part of the interactions with interested colleagues and collaborators, a series of workshops, devoted to selected areas of high interest (see open dots in Fig. 3, and Box 5 for earlier workshops). One such workshop, sponsored by the UBC, and the Department of Fisheries and Ocean, Canada, will be held on 6-10 November 1995, in Vancouver, B.C., Canada, and devoted to the construction of models of inshore and offshore areas of the Northeastern Pacific. Another workshop, tentatively planned for late in 1996, will compare ecosystems along the West

**Box 4. For a new start in aquatic food web studies**

In a recent study we estimated how much primary production is required to sustain the global landings and discards of fish; this yielded a global estimate of 8% of total primary production, with a low value (2%) for the open oceans, while the estimates for shelf systems were as high as 25-35% (Pauly and Christensen 1995). The analysis was done by splitting the world catches into 39 species groups (1) for which fractional trophic levels (TLi) were computed based on 48 published trophic models; average eutrophic transfer efficiency between trophic levels (TE) was estimated to 10% based on estimates from the same models (Fig. 4), and the catches (Ci) were raised to Primary Production Required (PPR) using the relationship PPR = catch TLi.1.

Earlier, we had presented new approaches for rigorous estimation of trophic levels and their variance (Christensen and Pauly 1992), for calculating the aggregate flows into and out of each trophic level of a given ecosystem (Ulanowicz 1995), and thus to estimate TE values by trophic level and ecosystem type. This approach now permits the re-evaluation and the testing of alternative hypotheses concerning empirical relationships established earlier, and based on indirect, and often rather inaccurate methods of unknown precision.

For example, Ryther (1969), when estimating world fisheries potential guessed all the TE values he used, states "Slobodkin [1961] concludes that an ecological efficiency of about 10% is possible, and Schaeffer [sic] [1965] feels that the figure may be as high as 20 percent. Here, therefore, I assign efficiencies of 10, 15, and 20 percent, respectively, to the oceanic, the coastal, and the upwelling provinces, though it is quite possible that the actual values are considerably lower."

When we look back at those attempts, it is tempting to quote Parsons et al. (1979), who wrote in a new classic textbook with regard to similar relationships that "by definition, these relationships are advanced as being the most acceptable at the time of writing the text but it is to be expected that researchers will improve or disprove many of the processes discussed in the light of future scientific advancement. Such is the nature of science." And now is the time.
Box 5. Using ECOPATH for training, education and research

Making an ECOPATH model is like taking a course in ecology. In the construction, main emphasis is on ecological relationships, not on the "modeling" per se. This feature has been made very clear by the courses and workshops conducted up to now — in Brazil, Canada, Germany, Malaysia, Mexico and Thailand.

At several universities, ECOPATH II is now being used as part of a curriculum, e.g., by letting students work with test datasets, or as teamwork where the students are assigned different parts of an ecosystem, then each group secures input parameters from fieldwork or the literature, while the final model construction is done in plenum. Construction of ECOPATH II models have also shown very useful for graduate studies, and to date more than a dozen MS and PhD theses have been completed using ECOPATH II as a structuring tool.

When constructing a model, information is needed of the trophic interactions of the entire ecosystem and this facilitates cooperation between, e.g., university researchers working on different ecological groups. As an example, production of prey must be sufficient to meet the requirements of the consumers. Therefore researchers who may perhaps otherwise remain focused on "their" groups of organisms must communicate, which may lead to cooperation, hypotheses testing, and other good things, such as publications presenting overviews of the important trophic flows in the system around a university field station.

ECOPATH models pertain to a certain time period. However, by producing new models year after year, for instance as part of regular coursework or surveys, the door is opened for analysis of time series of whole system properties — something that has been rarely done before.

Box 6. ECOPATH II and fisheries management

There is a link between constructing an ECOPATH model and doing management-oriented fisheries research. A precondition for managing the resources of an aquatic ecosystem is knowledge of these resources, e.g., what and how much is there? Further, the resource species impact on each other, predation usually being, by far, the single most important cause of mortality even in intensively exploited ecosystems. We thus need knowledge of trophic interactions, and the information in ECOPATH models is the basic information needed for the biological component of management.

We need more, however. We also want to know the likely consequences of changing fishing pressure, i.e., what will happen if the fishing effort for certain gears is decreased or increased? This cannot be done using ECOPATH models, even if the EcoRanger module (see Box 2) may indicate how changes in ecosystem structure might influence the fishery overall.

For fishery-induced changes on an ecosystem, another tool is needed: Virtual Population Analysis (VPA), which is widely used, though mostly in the Northeastern Atlantic. With this approach, the historic catches are used to "construct" the (virtual) population structure required to balance the catches. The approach can then be reversed to predict how changes in fishing pressure are likely to impact catches and population structure.

As it is of importance to answer "what if" questions using the VPA approach, one of us (V. Christensen) has worked over the last year on development of a robust version of multispecies virtual population analysis (MSVPA), taking biological interaction into consideration. This MSVPA builds on a model developed in the Northeast Atlantic area (see Sparre 1991) and has been documented elsewhere (Christensen 1995a); a text-version is available. It is planned to incorporate this into the ECOPATH II software, with which it shares many features. Release, however, will await publication of a number of test applications, and we therefore invite colleagues with interest in management of specific multispecies fisheries (preferably tropical) to notify us if they are interested in teaming up with us for this.

The data requirements are fishery catches for all important resource species in the study area, by month, and by length class, over at least an annual cycle. In addition some knowledge of biological interaction among the important fish species through stomach investigations is required. Please contact the first author for further information.

Coast of the Americas, from Alaska to Chile, and on to Antarctica. We welcome suggestions of additional workshops, including some that would be devoted to analyzing multispecies fisheries using Multispecies VPA (Box 6).

We expect these models and comparisons, and our planned work on globally important groups to lead to further generalizations, and also to regional integration of data — as did, e.g., our stratified models of the South China Sea (Pauly and Christensen 1993), now used to structure regional collaborative research by Southeast Asian research groups (UPMSI 1995).

Thus, when the global model emerges, we (including our partners) will be ready to incorporate into it all the insights gained at the local and regional levels, and we can use the global model for inferences on, e.g., human impact on the world ocean.

Box 7. Simulating changes

The Monte-Carlo routine built into the EcoRanger module of ECOPATH II (vers. 3.0) allows simulating the effect of ecosystem changes (including those induced by altered fishing patterns) on food web structure, a feature previously not thought amenable to study, at least not using the ECOPATH approach.

When simulating changes it is desirable to constrain the possible outcome(s), and to use optimization functions, commonly called goal functions (see Christensen 1994, 1995b), to select the most desirable outcome among the many possible.

In the new version of ECOPATH we have incorporated a number of such goal functions, ranging from E.P. Odum's "maturity" to Ulanowicz's "ascendancy". The constraints provided by user-selected parameter act as filters, and EcoRanger then selects from among them the best fitting one, using least-square criteria.

If a model is originally balanced with a given set of parameters, and a change is forced onto a system, e.g., in form of biomass changes due to changed fishing pressure or other induced stress, the outcome of the analysis will be a new, predicted, model with the structure that is most likely to emerge under these constraints.

The new approach provides a bridge between traditional static models and simulation models in that it maintains the key characteristics of the static models, notably preservation of mass balance for all components, and a parametrization built on few and transparent assumptions; yet it provides predictions of how the system is likely to change. This also opens a new avenue for testing of goal functions when they are not used themselves as filter.
Box 8. How to obtain the ECOPATH II software and its documentation

The ECOPATH II software for construction of trophic ecosystem models can be obtained as ICLARM Software 6 in a new, Windows-based release (Version 3.0) in addition to the previous DOS Version 2.2.

For new users, two possibilities exist, either to order the software with a printed manual for US$20 (including airmail) from ICLARM's Information Division, or to enroll as collaborators of the ECOPATH II project, in which case we will send the software free of charge. Please contact us if you choose the latter option.

For registered users of ECOPATH II, we will supply on request the new version free of charge, with the manual in electronic form free of charge. The printed manual can be airmailed at cost (US$15), while surface mailing is free.

The ECOPATH II software is copyrighted, but can be copied for free to colleagues and students as long as this is not done for commercial purposes. We encourage users to register (free of charge) as we can then keep informed of newly discovered "bugs". New releases, major publications (see Fig. 5), etc.

*The manual for the Windows version (3.0) of ECOPATH II presently exists only in English, while the manuals for the DOS version are in English, French and Spanish. There is considerable overlap between the manuals for both versions, and we recommend the French or Spanish manuals to users of the Windows version who may be more fluent in these languages than in English.

Some of these studies will include:

- producing estimates of biomasses and trophic flows in the world oceans, and in different ecosystem types both globally and regionally; the latter will provide a background for regional studies in many small countries;
- evaluating the role of zooplankton, and of fish (notably the mesopelagics) in the global carbon cycle;
- producing estimates of how much primary production is required to sustain the global fisheries and the ecosystem components that compete with them and assessing their impact on sustainability, and thus getting a handle on the carrying capacity of the world oceans;
- estimating catch potential using different fishing patterns, e.g., harvesting top predators or fishing down the food web, and evaluating the impact of alternative management strategies.

We anticipate that numerous additional questions of global, regional or local interest will emerge, many as a result of our collaborators' work, and we look forward to the interactions that this implies. Box 8 describes how the ECOPATH II software and its documentation can be obtained, and we conclude this with an invitation to all interested to contact us, either through ICLARM in Manila, or at our other addresses, in Hirshals and Vancouver, respectively.

References


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