



Placing fisheries resources in their ecosystem context

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(Fig. 1 - Christensen, 1996). It is therefore crucial to understand predation, i.e., the feeding ecology of resource species, and of their predators.

Fisheries research in the northern temperate areas has in recent years focused attention on analyses of multispecies interactions. This has led to development of a number of tools, but not yet to any consensus on a single methodology for use in a variety of areas.

In tropical waters, multispecies assessment is in its infancy. Here, emphasis has been on developing and disseminating methods for

single-species analysis, notably through the Network of Tropical Fisheries Scientists, NTFS, run by the International Center for Living Aquatic Resources Management, ICLARM and through the FAO/Danida Tropical Fish Stock Assessment Training Programme, both of which have been on-going for nearly two decades. The problem of species interaction, however, looms larger in tropical waters than in temperate areas, and hence there is considerable interest in a transition toward multispecies assessment.

Unfortunately, the methods developed for multispecies analysis in temperate areas are

Fish eat fish

The 95 States represented at the International Conference on the Sustainable Contribution of Fisheries to Food Security in Kyoto, Japan, December 1995, agreed among other things "[to] conduct, within their competences, and where appropriate, in cooperation with regional and other intergovernmental organizations, integrated assessments of fisheries in order to evaluate opportunities and strengthen the scientific basis for multispecies and ecosystem management."

Much will have to be learned and done before we can live up to this part of the Kyoto Declaration. Thus, in order to manage exploited marine ecosystems, we must increase our knowledge of the resources they contain. Fisheries management has for decades focused on obtaining information on catches, and on stock sizes of the exploited resources; this has been done, however, largely on a species-by-species basis. Over time, it has become increasingly obvious that fisheries resources interact, and that the strength of their interaction is usually far more important than the impact of fisheries. Thus, on a global scale, predation outweighs fisheries more than threefold

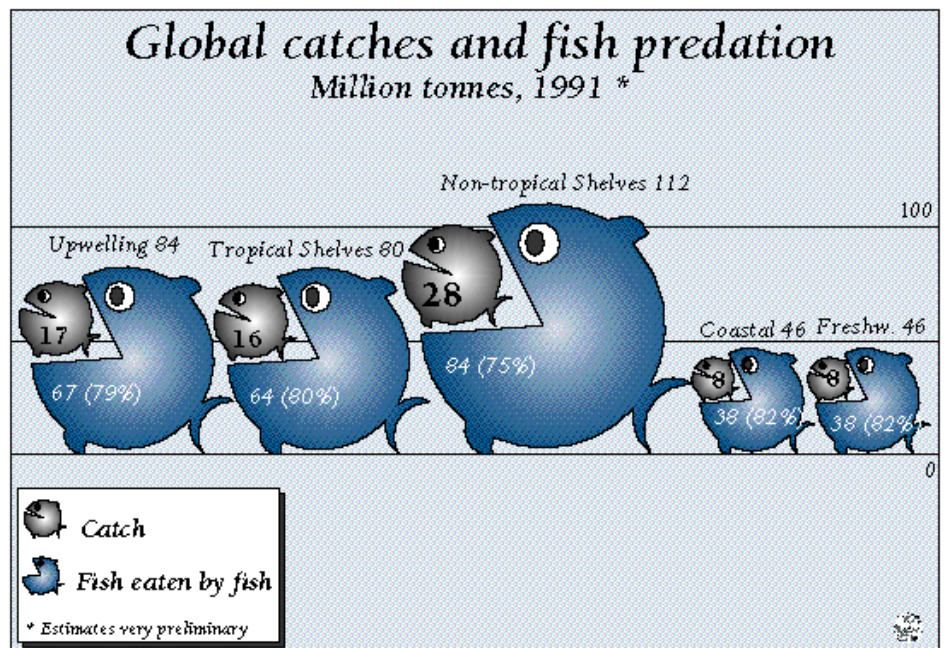


Fig. 1 - Relative importance to the fate of fish, of fisheries catches and fish predation in different types of aquatic ecosystems. Note the overwhelming effect of predation, the reason why fisheries management must be embedded in an ecosystem context. - Importance relative de la pêche et de la prédation sur la vie pour les poissons dans différents types d'écosystème aquatique. Remarquez l'effet prédominant de la prédation, la raison pour laquelle la gestion des pêches doit être intégrée dans le contexte de l'écosystème.



not directly applicable for tropical use as they are all age-based. On the other hand, routine-cost-effective aging of tropical fish species appears unfeasible. Moreover, even if these multispecies methods did not have this aging problem, they would be far too demanding to be of much use in the mostly developing countries in the tropics. Hence, considerable interest has focused in developing countries on the use of relatively simple mass-balance models, and which paves the way to multispecies management (Fig. 2). Such models are structured by feeding interactions, and by the resulting 'trophic' fluxes of matter or energy. Thus, they can be used to link fisheries resources with their supporting ecosystem (i.e. the prey and predators of the resource species).

Ecopath modelling

At present, work with mass-balance models has been published or is underway among a large number of fisheries scientists in developing countries as well as in the European Union and North America. This development has to a large degree been pioneered by the introduction and use of the Ecopath software developed at ICLARM, based on initial work by Dr. J. Polovina at the South West Fisheries Center, Hawaii, USA. This software has been widely distributed since 1990 (more than 500 registered users in 75 countries), and a large number (60+) of models of aquatic ecosystems have been published with a similar number in press or preparation.

A beauty of the Ecopath approach is that models can be constructed by combining local, and previously underutilized data sets, with regional, published information. Moreover, the data requirements of Ecopath models are themselves very limited: for all important ecosystem components production, from algae over exploited fish species to marine mammals, the input must specify the amounts (i.e., the biomasses), their productivity (i.e., their mortality rates), how they interact (i.e., diet compositions and consumption rates), and what fraction of each component's is consumed within the ecosystem. In addition, information on catches is needed on a species, preferably on a fleet/gear basis. Seasonality can, where important, be incorporated in the models, as can uncertainty about the inputs (through the inclusion of very wide ranges or of distributions, for every single input, see below).

At present the knowledge of multispecies interactions of importance for ecosystem management may seem very sparse. However, large amounts of scattered information are available from previous and ongoing studies –much of it retrievable through FishBase (Froese & Pauly, 1997; Pauly in this issue of the Bulletin).

Not all information needs to be available for input though: based on the requirement of what comes into any component of the system must match what comes out, the software calculates what the 'missing' parameters must be in order to secure mass-balance. Moreover, this can be done through explicit consideration of uncertainty in input parameters, through sensitivity analysis and through a Bayesian approach which generates posterior distributions of input values, besides distributions of output values.

The key results of Ecopath analysis are validated information on the resources of an ecosystem, and how they impact each other. A time dimension can be added to this, in two ways. Firstly, by constructing several models, each covering a different time period, and subsequently comparing these. Secondly, through a recently incorporated, dynamic simulation module, Ecosim, developed by Prof. Carl Walters of the Fisheries Centre, University of British Columbia, Canada (Walters *et al.*, 1997). In Ecosim, the system of coupled linear equations underlying each balanced Ecopath model is re-expressed as a system of coupled differential equations, allowing simulations of ecosystem perturbation in time, i.e., through change in fishing regime. The resulting dynamic simulation models do not require additional parameters to run, making it possible for users to concentrate on data analysis, and interpretation and not on model construction per se. This represents a strong contrast to all earlier, and most other recent modelling approaches.

Economic factors can be considered in Ecopath/Ecosim through inclusion of market prices for the exploited components of an eco-

system, thus allowing comparison of revenue flows when evaluating alternative management strategies (on a gear or fleet basis). Also, various these strategies can be compared with non-extractive resource uses, e.g. eco-tourism.

INCO-DC cooperation and comparisons

As a response to the INCO-DC call for proposals in September 1996 a project or 'concerted action' was to link, through open, voluntary and pro-active cooperation, the researchers in Europe, Africa, the Caribbean and Latin America who are working with or are interested in mass-balance models of marine ecosystems. The proposal was approved following competitive peer-review and one immediate result is that a number of regional training courses and workshops can now be organised to ensure that potentially interested partners will learn how to use Ecopath to construct models of systems in their own countries (Fig. 3). These models will then be presented, discussed among the participants, and analysed comparatively at two international workshops that will synthesise the major results of this collaboration.

Thus, this concerted action will promote an intercontinental 'laboratory without walls' where scientists from 31 institutions in 25 countries will be given a forum for cooperation. As the major part of the partners come from ACP and EU countries, this offers an avenue for synergistic cooperation with the ACP-EU Fisheries Research Initiative (see the permanent column about the Initiative in this

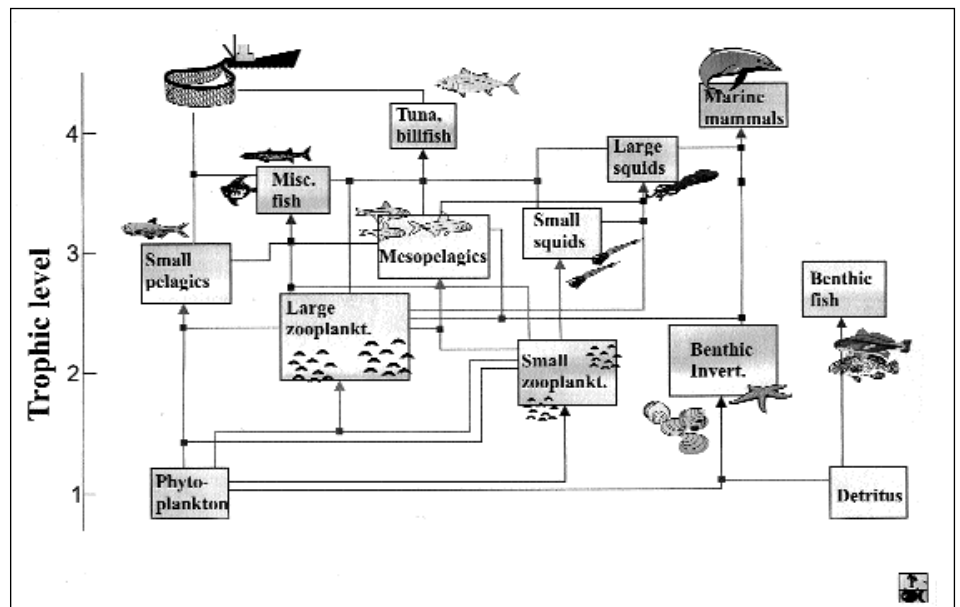


Fig. 2 - Simplified flowchart of an Ecopath model representing the Southern South China Sea, with the size of the boxes representing their relative biomass. Note, in this example, the separatedness of the food webs leading to the fisheries, and to the marine mammals, respectively. - Représentation simplifiée d'un modèle Ecopath représentant la partie sud de la Mer de Chine Méridionale, dans lequel la taille des boîtes représente les biomasses relatives. Notez dans cet exemple la séparation des chaînes trophiques menant respectivement aux poissons et aux mammifères marins.



Bulletin and the proceedings of the three regional dialogue meetings between ACP and EU partners - Anon, 1995, 1996, 1997). Emphasis will thus be on research that leads to ecosystem management in both ACP and EU countries. This is in line with the Fisheries Research Initiative, which has as a major purpose to adopt and implement a strategy for the conservation of Large Marine Ecosystems (LMEs) by coastal states and the international community (Christensen & Mahon, 1997). Conserving the resources of LMEs requires that these resources be assessed, their fisheries are sustainable, and hence embedded in an ecosystem context. A methodology for reaching these aims still have to be developed, but it is anticipated that Ecopath and Ecosim, which will themselves evolve during the duration of this collaboration, will strongly contribute to the emergence of this methodology.

An important aspect of the planned activity is that it focuses on analyses and management of exploited ecosystems, not just on management of their components. Further, it is expected that the action will allow refining the criteria that are presently being developed as part of certification schemes for eco-labelling of fishery products. Both of these issues will have far-reaching effect on domestic fishing industries in the countries concerned, and for their governments. This will ensure the practical relevance of the research described here.

To construct mass-balance models, information is needed on resources at all trophic levels from phytoplankton to sharks, sea birds, marine mammals and fisheries. The experience from prior applications shows that the process of obtaining such information strengthens inter- and intra-institutional cooperation within and beyond that normally practiced among fishery scientists. In addition, the scientists involved in the modelling gain information on ecosystem functioning and on ecosystem management, leading to insights much deeper than those based on applying the precepts of single-species schemes.

Comparisons will play a very important role in this concerted action. Temporal or latitudinal comparisons of ecosystem impact of fisheries are sparse to non-existent in the scientific literature. Thus, we will rely heavily on inter-ecosystem transects as a tool for gaining new understanding of these impacts and related ecosystem processes. The collaboration will lead to comparisons within transects from Europe to Africa, from the Caribbean to the southern tip of Latin America, and all along the coast of the Eastern Pacific. Comparisons among islands systems and oceans will also be possible. By bringing together scientists with common problems and interests and by building on data from numerous ecosystems, we anticipate that cooperation and conclusions will emerge reaching far beyond what has so

far been obtained from working individually on local scales only.

Implementation

The project deals with two major regions: Atlantic, including Caribbean waters and the Pacific coast of Latin America, both to be 'stretched' northward by using Ecopath models so far (or which will be) published for areas in North America. It has attracted a total of 31 participating institutions as partners. This strong interest shows that there is a growing concern and need for ecosystem management as expressed in the Kyoto Declaration. The willingness to participate further shows that the time has come to take action as shown by the Dialogues of the ACP-EU Fisheries Research Initiative in Dakar and Belize, respectively (Anon, 1996, 1997). These facilitated communication and participation in the ecosystem modelling activity.

For each of the two major regions to be covered by the collaboration, the planned activities include:

- Establishment of communication channels within and between regions, with emphasis on electronic mail;
- Organisation of regional training courses to ensure that all partners share a common methodology and information base;
- Preparation by each partner of one or more mass-balance models for their area of interest;
- Holding of regional workshops for groups of partners with special interests;
- Holding of a major synthesis workshop after a sufficient number of local models have been prepared.

The synopsis workshops, which will be decidedly international, will also be open to participants not formally involved in the concerted action, as a wider ecosystem coverage will broaden the comparisons that can be made during the workshops. The workshops will provide an opportunity for active researchers to discuss and compare their ecosystem analyses, as well as topics such as north-south comparisons, gradients of fisheries impacts, and ecosystem criteria for eco-labelling of fishery products.

Conclusion

The foregoing may appear to some as the description of a run-of-the mill project, in which yet another group of biologists will amuse themselves doing pretty graphs. Yet what we have described is an activity that numerous previous research projects intended to carry through - such as the famous International Biological Programme - but which they could not implement for lack of suitable software tools.

We believe it will be possible to show through this concerted action not only that embedding

fisheries within their supporting ecosystems is possible, but that it is so straightforward as to be applicable throughout the world, even in data-sparse areas that had previously defied such efforts.

We are convinced that this ecological embedding of fisheries will contribute to their reconceptualisation as sustainable activities. We are aware, however, that such reconceptualisation will also require embedding the ecosystems themselves in a 'New Covenant' with a society that has become aware of the intrinsic values of natural ecosystems.

References

- Anon, 1995. ACP-EU Fisheries Research Initiative. Proceedings of the First Dialogue Meeting, Eastern and Southern Africa, Indian Ocean and the European Union. Swakopmund, Namibia, 5-8 July 1995. Brussels, *ACP-EU Fish.Res.Rep.*, (1):144 p.
- Anon, 1996. ACP-EU Fisheries Research Initiative. Proceedings of the Second Dialogue Meeting, Western and Central Africa and the European Union. Dakar, Senegal, 22-26 April 1996. Brussels, *ACP-EU Fish.Res.Rep.*, (2):166 p.
- Anon, 1997. ACP-EU Fisheries Research Initiative. Proceedings of the Third Dialogue Meeting, Caribbean and Pacific and the European Union. Belize City, Belize, 5-10 December 1996. Brussels, *ACP-EU Fish.Res.Rep.*, (3):180 p.
- Christensen, V. 1996. Managing fisheries involving predator and prey species. *Reviews in Fish Biology and Fisheries*, 6:417-442
- Christensen, V. & D. Pauly (eds.) 1993. Trophic Models of Aquatic Ecosystems. *ICLARM Conf. Proc.*, 26, 390 p.
- Christensen, V. & R. Mahon, 1997. Researchable issues relevant for management of Large Marine Ecosystems, with special reference to the Caribbean. pp. 79-100 IN Anon, 1997. ACP-EU Fisheries Research Initiative. Proceedings of the Third Dialogue Meeting, Caribbean and Pacific and the European Union. Belize City, Belize, 5-10 December 1996. Brussels, *ACP-EU Fish.Res.Rep.*, (3)
- Froese, R. & D. Pauly (eds.), 1997. FishBase '97. Concepts, design and data sources. Manila, ICLARM, 256p.
- Pauly, D., 1997. The science in FishBase. *EC Fish.Coop.Bull./Bull.Coop.Pêche CE*, 10(2): 4-6
- Walters, C., V. Christensen & D. Pauly. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. *Reviews in Fish Biology and Fisheries*, 7:139-172 ■

