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Modelling the Mekong Fisheries: What Can Be Done?

(Eric Baran, ICLARM)

Modelling the fish resource and its exploitation in a system as complex as the Mekong River is a challenging exercise. First there are annual variations in the timing, duration and extent of flooding that strongly influence the natural fish production targeted by fishermen. Second, the fishing methods are very diverse (more than 150 types of gears), seasonally operated, distributed over an area of floodplains as vast as Ireland, and therefore difficult to monitor. Third, data are scant and there are no long time-series. These constraints call for an innovative approach to fisheries modelling.

Modelling: what tools, what for?

Modelling, whatever the method, comprises several steps: definition of the modelling objective; definition of the system studied; formulation of a conceptual model; formulation of the mathematical and computer model; validation and application.

In the case of the Mekong fish and fisheries, we are presented with a complex case where the object of interest is poorly understood, requires research, and urgently needs sound management tools. Thus all the usually distinct aims of modelling are here simultaneously required: identification of critical questions; building of a conceptual framework synthesising the different perceptions of the various stakeholders; synthesis of existing knowledge and identification of knowledge gaps; production of simulation scenarios and provision of advice to managers.

Assuming that modelling fisheries is aimed at i) understanding the functioning of the system; ii) predicting the future of the fishery (fish and fishers) under different scenarios, and iii) providing sound advice to decision-makers, we briefly review here four categories of modelling: classical fishery modelling, ecological, Bayesian and multi-agent modelling.

Classical modelling approaches

Traditional fishery modelling

Common global and analytical models require data on harvested biomass (catch statistics), virgin biomass, catchability, fishing effort, growth, stock-recruitment relationships, etc. Such data are not available even for dominant commercial Mekong fish species, not to mention the hundreds of rarer species. These models also require long time series of data to encompass biological variability. Furthermore these classical fishery models have been heavily criticised for their simplistic initial assumptions, ignorance of social and economic factors, and general failure (Caddy & Mahon 1995, Beverton 1998, Holt 1998, Pitcher *et al.* 1998). For these different reasons a comprehensive and reliable model of the Mekong fisheries based on classical fishery models may be difficult to achieve in the near future.

Ecological modelling

Existing ecosystem models such as Ecopath or Ecosim (Christensen & Pauly 1992, 1993, Walters *et al.* 1997) require data on biomass of certain groups (e.g. phytoplankton, zooplankton, benthos, etc) and on related trophic flows that are simply non-existent for the Mekong system.

Similarly, individual-based ecological modelling has recently been subject to severe criticisms, mostly due to its extreme complexity and multiple underlying assumptions (Grimm 1999, Grimm *et al.* 1999).

Alternative modelling approaches

In a complex environment with multiple interacting factors (such as fish groups, fishers, farmers, dams, etc) equation-based approaches have limitations. Chief amongst them are feedback loops between factors and the lack of data for many interactions. Similarly, purely statistical approaches are also limited, as the number of variables and their interactions would require, for proper testing, an unrealistically large number of test sites.

Models based on computer simulations provide an alternative and recent solution to this problem. We present here two approaches, based either on Bayesian networks (Jensen 1996) or on multi-agents (Ferber 1999, Bousquet *et al.* 1999). In both these approaches, i) major interacting compartments of the system are identified; ii) a synthetic representation of the system is built; iii) interactions between compartments are characterised; iv) the consequences of a given management decision, based on the sum of interactions, is predicted.

Bayesian modelling

This modelling is based on variables representing the modelled environment. Variables can be quantitative (e.g. “Flood level”) or qualitative (e.g. “Migrating species”, “Subsistence fishers”, etc). A variable is defined by classes (e.g. variable “Flood level” can be Low/Medium/High, or actual values can be entered when available).

These variables are connected together by links expressed in terms of probabilities (e.g. if variable “Flood level” is High, there is an 80% chance that variable “Fish production” is Good). These probabilities are defined in consultation with experts in the specific area (in our example, fisheries biologists and local fishermen), or from the scientific literature whenever possible.

The interactions between multiple variables consist in conditional probabilities, and the model calculates the trend resulting from the sum of interactions within the system. Different scenarios can be considered by modifying the variables, and sensitivity analysis can point out variables that are critically important.

Bayesian networks have been developed in the mid-90’s to build Decision Support Systems. They are intuitive and easy to compute, making excellent tools for communication between stakeholders. They have been developed in particular for Integrated Natural Resources Management (Cain 2001), and are being applied to Mekong fish resources (Baran and Cain 2001, Baran and Baird 2001).

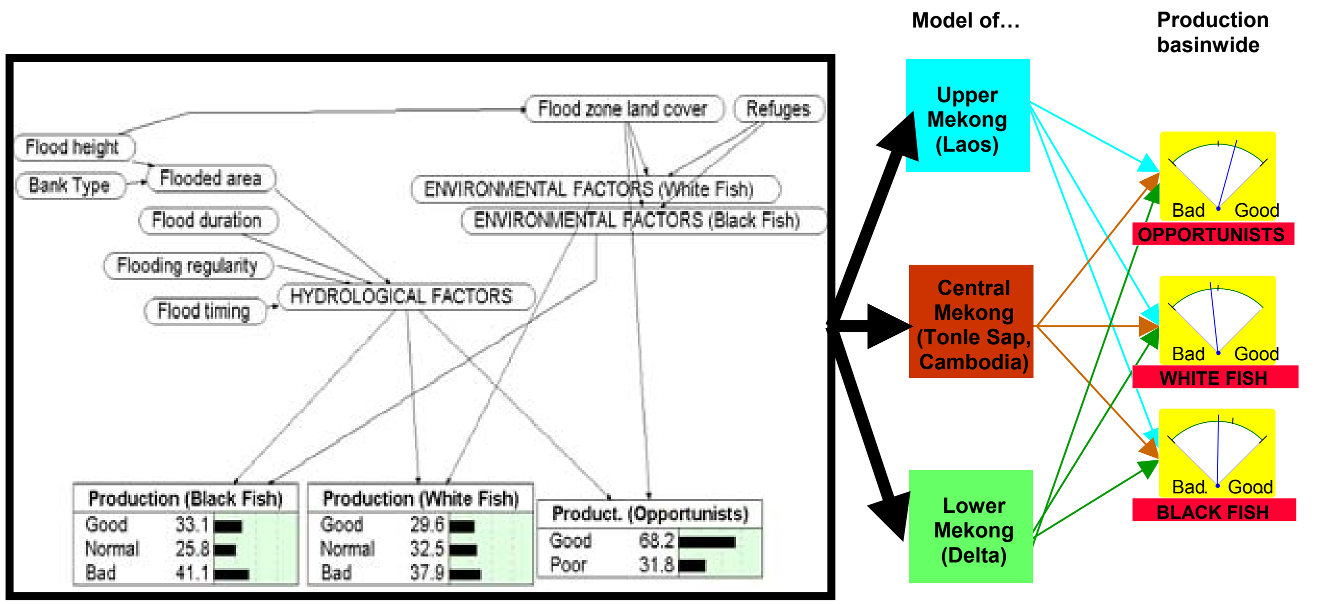

Figure 1: Model of the Mekong fish production based on Bayesian networks.

Several classes and corresponding probabilities are defined for each variable of the network; for better readability they are not all displayed in this picture.

Multi-agent modelling

This modelling is based on "agents", or elements of the system, that interact together (e.g., rice field fishes, flooded forest fishes, professional fishers, farmers, etc). The action of one agent on another is transmitted to other connected agents depending upon their respective interactions. This includes diverse degrees of action and feedback loops.

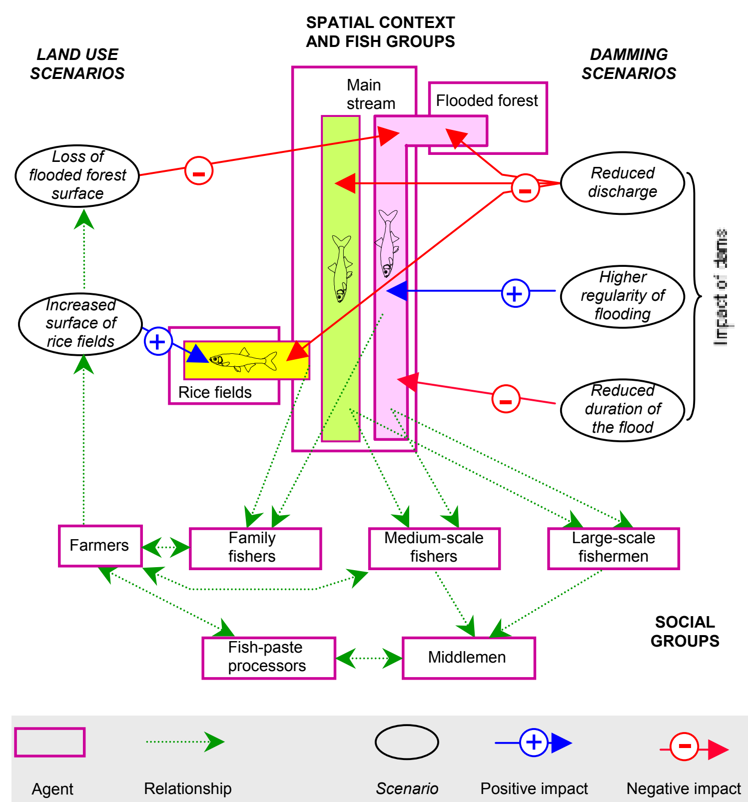

Figure 2: A model of interactions between some agents of Mekong fisheries

Multi-agent frameworks have already been developed for different biological and management systems (Sichman *et al.* 1998, Moss & Davidsson 2000) and are being developed in Europe for freshwater integrated resource management (FIRMA 2000). Tropical river fisheries have already been addressed this way in the Niger inner delta (Bousquet 1994).

The value of such an approach and tool is that it allows the simulation of interactions between agents at various geographical and social levels. Recent developments also allow the modelling of complex decision-making processes for agents with internal control capacities (integration of learning, weighted options). The conceptual stage of this modelling, being fairly intuitive, also allows multiple stakeholders and decision-makers to take part to the process (Lynam *et al.* 2002).

Conclusions

Managing the fish resource in a shared environment consists in addressing three successive levels: fish and their environment; then the users of the environmental resources; then the local and national management bodies. In a holistic approach, this corresponds to three layers of increasing complexity, in which agents, interactions and constraints have to be successively identified (Figure 3).

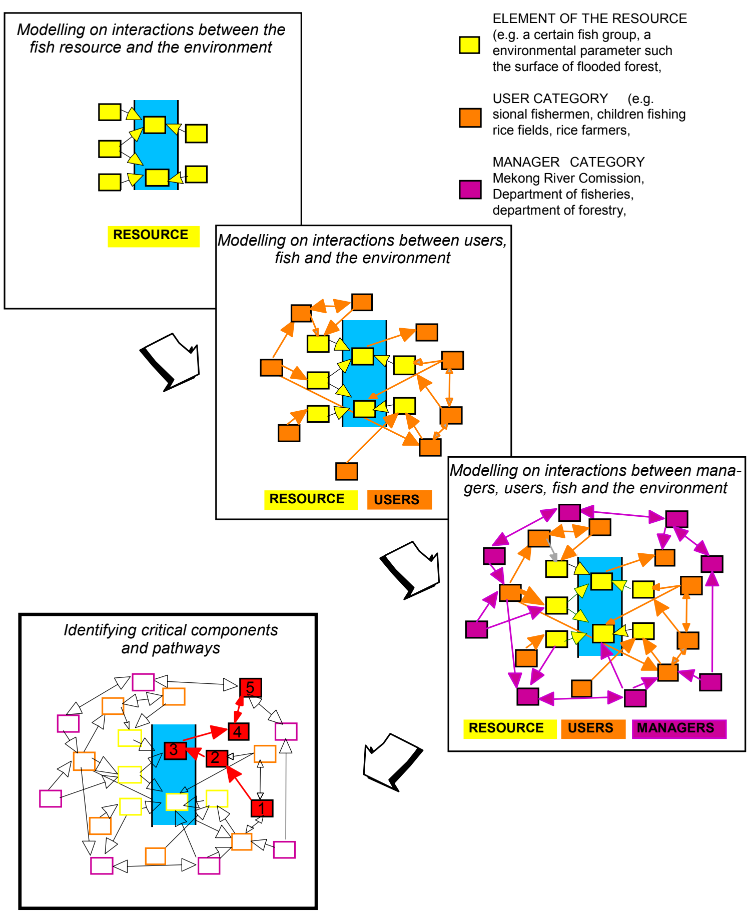

Figure 3: The principal steps of systemic modelling in the case of Mekong fisheries

Tharme (2002) has recently shown that this new generation of holistic models was mostly being designed and applied in tropical countries. This reflects the fact that in these countries, people are strongly linked to natural environments and their dynamics, and dependant upon rivers and their aquatic resources. Modelling now offers the integrative tools needed for a comprehensive management of river and floodplain resources.

Bibliography

Baran E., Baird I. 2001 Approaches and tools for sustainable management of fish resources in the Mekong River Basin. Proceedings of the International Symposium on Biodiversity Management and Sustainable Development in the Lancang-Mekong River Basin. 4-7 December 2001, Xishuangbanna, Yunnan, China. *In press.*

Baran E., Cain J. 2001 Ecological approaches of flood-fish relationships modelling in the Mekong River. Proceedings of the National workshop on Ecological and Environmental Modelling, 3-4 September 2001, Universiti Sains Malaysia, Penang, Malaysia. *In press.*

Beverton R.J.H 1998 Fish, fact and fantasy: a long view. Rev. Fish. Biol. Fish. 8 (3) 229-250

Bousquet, F. 1994. Distributed artificial intelligence and object-oriented modelling of a fishery. Mathematical Computer Modelling 2018:97-107

Bousquet, F., O. Barreteau, Le Page C., Mullon C., Weber J.1999. An environmental modelling approach: the use of multi-agent simulations. *In* Blasco & Weill (eds) Advances in ecological and environmental modelling, Elsevier.

Caddy J.F., Mahon R. 1995 Reference points for fishery management FAO Fisheries Technical Paper n° 347- FAO Rome, 83 p.

Cain J. 2001 Planning improvements in natural resources management. Guidelines for using Bayesian networks to support the planning and management of development programmes in the water sector and beyond. Center for Ecology and Hydrology, Wallingford, UK. 124 pp.

Christensen V., Pauly D. (eds.) 1993 Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390 p.

Christensen V., Pauly D. 1992 Ecopath II- a system for balancing steady-state ecosystem models and calculating network characteristics. Ecol. Modelling 61: 169-185

Ferber, J. 1999 Multi-agent systems: an introduction to Distributed Artificial Intelligence. Reading, MA, Addison-Wesley.

FIRMA 2000 Freshwater Integrated Resource Management with Agents. A project supported by European Union ("Framework 5 Programme for Research and Development") and by the European Commission ("Key Action on Sustainable Management and Quality of Water programme") Web site: http://firma.cfpm.org

Grimm V. 1999 Ten years of individual-based modelling in ecology: what have we learnt and what could we learn in the future? Ecological modelling 115 129-148

Grimm V., Wyszomirski T., Ailman D., Uchmanski J. 1999 Individual-based modelling and ecological theory: synthesis of a workshop Ecological Modelling 115 275-282

Holt S. J. 1998 Fifty years on. Rev. Fish Biol. Fish. 8 (3) 357-366

Jensen F.V. 1996 An introduction to Bayesian networks. UCL press, London. 178 pp.

Lynam, T., F. Bousquet, C. Le Page, P. d'Aquino, O. Barreteau, F. Chinembiri, and B. Mombeshora. 2002. Adapting science to adaptive managers: spidergrams, belief models, and multi-agent systems modeling. Conservation Ecology 5 (2): 24

Moss S., Davidsson P. (Eds.) 2000: Multi-agent-based simulation. Second international workshop MABS 2000, Lecture Notes in Computer Science vol. 1979 Springer-Verlag, Berlin.

Pitcher T.J., Hart P.J.B., Pauly D (eds.) 1998 Reinventing fisheries management. Chapman and Hall, London.

Sichman J., Conte R., Gilbert N. (Eds) 1998 Multi-agent systems and agent-based simulation. Proceedings of the First International Workshop MABS '98. Lecture Notes in Computer Science, Vol. 1534, Springer-Verlag, Berlin.

Tharme R. E. 2002 A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. Submitted to Rivers Research and Applications.

Walters C.J., Christensen V., Pauly D. 1997 Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Rev. Fish Biol Fish. 7 137-172