HYDRO-BIOLOGICAL MODELS FOR WATER MANAGEMENT IN THE MEKONG RIVER

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Abstract: Among users of the water resource are fishes and fishermen. Given the importance of fisheries in the Lower Mekong River Basin, water management schemes must take the fish resource into consideration. Therefore hydrological modelling must encompass hydrobiological issues of critical importance for fisheries. This presentation is an overview of the practical aspects of modelling the relationship between water flow and fish production. The different ways of addressing this issue are listed, together with their corresponding data requirements. Basic production models address the relationship between fish production and water discharge, and the relationship between flooded surface and fish production. More refined production models focus on the impact of the dynamics of the flow, such as duration, timing, consistency. In addition to hydrology, environment must also be taken into consideration for a proper management of the fish resource.

Keywords: Mekong, Fishery, Flood, Model

Reference:
Baran E., Coates D. 2000 Hydro-biological models for water management in the Mekong River. Pp. 328-334 in Al-Soufi (Ed.) Proceedings of the Workshop on hydrologic and environmental modelling in Mekong Basin, Phnom Penh 11-12 September 2000. Mekong River Commission publications, 382 p.

I) INTRODUCTION

The dominant importance of fish as a food resource in the Lower Mekong River Basin, detailed by Coates in another contribution to this workshop, implies that water management schemes should take the fish resource into consideration. Therefore management decisions must encompass hydrobiological issues of critical importance for fish and fisheries (Petr 1985).
These issues are considered as "critical" in relation to two major criteria: fish production (sustainability of the food resource) or biodiversity (sustainability of the biological heritage and integrity of the system). Our approach here is based on the fish production criterion, and we propose in this paper an overview of the practical aspects, in the regional context, of assessing the relationship between water flow and fish production (Stalnaker et al. 1989).
Fish production has been proven to depend on hydrology, but also on the quality of the environment and on the mortality rate caused by fisheries (Bayley 1995, Hoggarth et al. 1999 a). A global modelling of the fish production should thus encompass these three aspects:

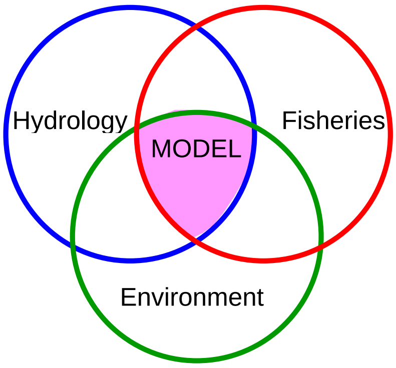

Figure 1: fish resource modelling and corresponding fields to be addressed

In the sections below we detail the hydrological issues to be addressed for an assessment of fish production in relation to water flow variation, then we also mention the environmental issues of importance for the sustainability of this production.

I) Simple production model

I-1) Catches vs. Discharge

Several studies worldwide have shown a correlation between the discharge and the *total catch* (in tons) 0 to n years before (Welcomme 1985, Bayley & Li 1992); the relationship is:

$$\mathbf{C_y = a.(D_{y-n}) + b}$$

C = total catch (tons) D = average discharge ($m^3.s^{-1}$)
y, y-n = years a & b =coefficients

However the catch results both from fish availability and from fishing effort, so whenever possible it is preferable to focus on Catch Per Effort (CPE = ∑ Catch Per Unit Effort) (Bayley 1988, Moreau & De Silva1991), the effort being usually the number of fishing gears and number of day/hours of fishing.

$$CPE_y = a.(D_{y-n}) + b$$

CPE = total catch per effort (tons)
D = average discharge ($m^3.s^{-1}$)
y, y-n = years a & b =coefficients

I-2) Catches vs. Area of floodplains

The common background to tropical flooding rivers worldwide is the importance of floodplains (Welcomme 1985) favourable to fishes because of:
- nutrition, via the release of nutrients from the ground during the flood. These nutrients allow the production of algae, of young vegetation, of phyto- then zooplankton which feeds juvenile fish. Then these juveniles and other vegetal feed the young carnivorous fish;
- shelter: shallowness and vegetation cover in flooded zones enhance the escapement rate and the survival of juveniles, on a significant extent;
- diversity, with the provision of numerous environmental and trophic niches for multiple species and strategies;

Assessing the relationship between catches and surface of floodplains (e.g.: Halls & Payne 1974) is equivalent to calculating the following relationship:

$$CPE = a \, . \, A + b \quad \textit{or} \quad C = a \, . \, A^{b}$$

CPE = catch per effort (tons) A = surface of floodplains
y, y-n = years a & b =coefficients

In this relationship it is assumed that the bulk of the catch is related to the flood the same year; however the relationship between the catch and the surface of floodplain 1 to n years before must be checked. In that case, the relationship is:

$$C_y = a \, . \, A_{y-1} + bA_{y-2} + \ldots + xA_{y-n}$$

C = total catch (tons) A = surface of floodplains
y, y-n = years a, b, c =coefficients

Practically speaking, flooded area can be considered as the annual average of daily flooded surfaces (calculated by an hydrological model):

$$(\text{Surface flooded})_{year} = \sum (\text{surface flooded})_{day} / \text{number of flooded days}$$

II) Refined production model

2-1) Hydrological parameters

The role of these flooded zones on fish survival and growth and therefore on the global fish production usually depends a lot on the flood parameters, such as its height, duration, timing,... We detail below these effects.

II-1-1) Characteristics of the flood

Height
In a given zone, a local configuration or man-made embankment might create a critical threshold under which the adjacent wetlands will not be flooded. The relationship between water level and flooded surface might not be linear, so these parameter have to be considered independently.

Duration
It is considered that a longer period of flood allows a longer growth of fishes, and therefore a higher yield. Furthermore, diverse combinations of surface and duration have very different biological consequences, so the simple product of surface by duration is not precise enough for fish production assessment purposes. The impact of a 5-days flood over 100 square kilometres is different from that of a 100-days flood over 5 square kilometres (500 km^2-days in both cases). Practically, duration (referring to flooded days above) can be the number of days of water spreading out of the river bed, and the couple duration-surface can be approached by two ways:
- multiple regression **Production = f^n (Duration, Area)**

- segmentation of the flood curve into n segments of variable duration, and calculation of:

$$\sum (\mathbf{Area}_i \,/\, \mathbf{segment}_i) \,/\, \textbf{number of segments}$$

Timing
It seems that the beginning of the flood acts as a signal for adults of many species to spawn upstream in the Mekong, and for their eggs and juveniles to drift downstream where they enter the Tonle Sap area and grow.
The timing of flooding can be expressed by the n° of the week at which the flood starts.
Example: if the flood starts the 2nd week of May (19th week of the year), timing factor = 19
In that case, a "starting point" must be defined, and this would be the yearly minimal water level averaged over a period of x years.

II-1-2) Consistency of flooding

Small drought periods in the course of the rainy season can result in massive mortality of fish eggs and fry. This leads to the notion of a Consistency Index, expressed as:
* the number of days with a water height (H) *decrease* between the beginning of the flood and the peak (recession days in the flooding period).
* the number of days with a water height *increase* between the peak and the end of the flood (flooding days in the recession period)

CI = (n° of recession days in the flooding period) + (n° of flooding days in the recession period)

$$\mathbf{CI = \sum [\ NB\ (H_d < H_{d-1})_{flooding}]\ +\ [\ (NB\ (H_d > H_{d-1})_{recession}]}$$

Alternatively, this irregularity of the flooding process can also be quantified by the following jaggedness index J (Figure 2):

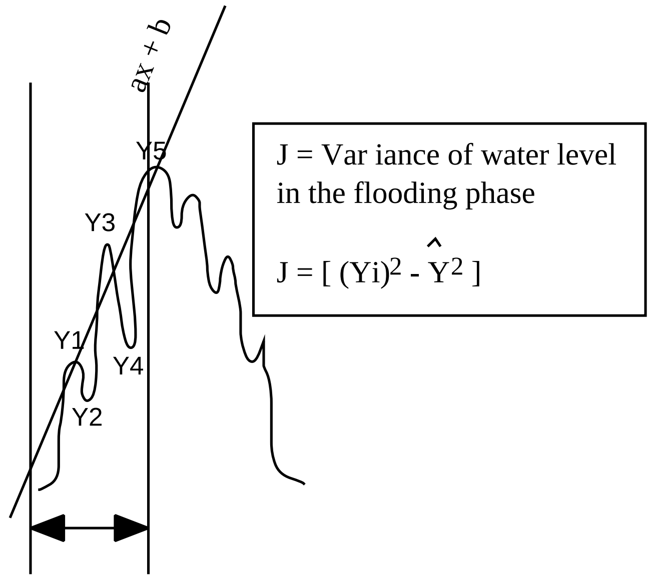

Figure 2: Quantification of the jaggedness of the flood

In this formula, square Y accounts for a greater biological effect at higher flood volumes (larger surface flooded). The area under the curve is the total volume (flow x duration).

II-2) Environmental parameters

II-2-1) Importance of refuges

Depressions in the dry season act as refuges for fish, allowing them to recolonize flooded areas in the next season (Hoggarth et al. 1999 b)
An index of refuges in the dry season is to be used, such as:

Cumulative surface of ponds / total surface of floodplain

II-2-2) Importance of the type of vegetation in the floodplain

The type of flooded zone is important for the feeding of fish. A grassland provides less food resource and less habitat diversity than a flooded forest. Therefore the *quality* of the wetland should be taken into account (Junk & Furch 1993, Welcomme 1995). This refers in the case of the Mekong to the Wetland classification project and to the assessment of surfaces of the different zones in the four riparian countries.

II-2-3) Turbidity

Turbidity has been mentioned as a parameter of importance in the dry season. In large wetland zones, fish intensively feed on filamentous algae. The abundance of these algae depends on water turbidity for photosynthesis. The huge quantity of fishes feeding this way might make turbidity a factor impacting significantly the total fish biomass.

2-2) Fisheries parameters

For many species, it seems that there is a migration of juvenile fishes from upstream down to the Great Lake at the beginning of the rainy season. After the rainy season spent feeding and growing into the Lake, fishes leave it to migrate back. On their migration route they are intensively fished. Assessing the impact of fisheries on the resource currently is a major task at the MRC Fisheries Unit, requiring an heavy sampling protocol. Once the impact quantitatively assessed, this require management measures (Scuder & Conelly 1985) out of the scope of this paper.

II-3) Conclusions

Building a model of the potential resource yield and of the consequences of altered flow rates requires a global approach involving data on fisheries, on environment and on hydrology.
In each of these components, several variables have been identified as influencing catches. From a practical point of view, this leads to an analysis of the relationships between the following variables (Figure 3):

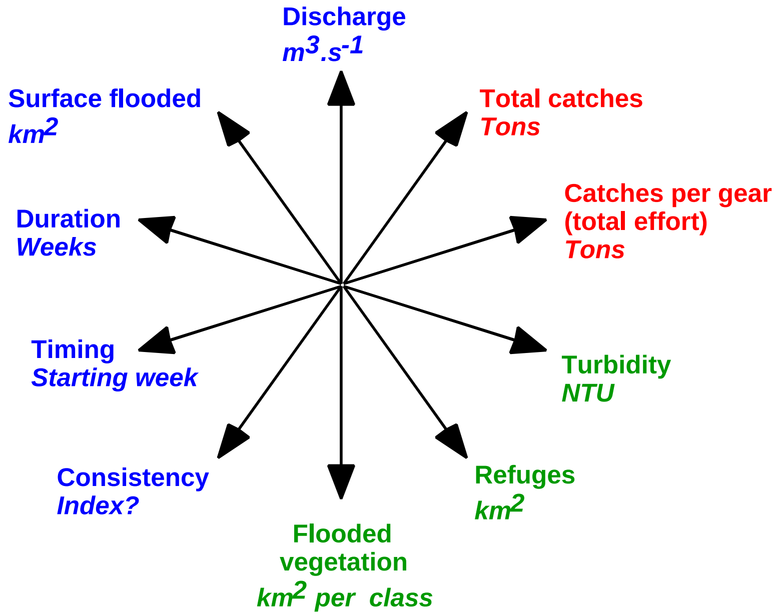

Figure 3: Variables to be taken into account for a fishery resource model in the Mekong basin

This approach can be considered at different scales:

Basinwide (e.g.: impact of certain fisheries on other fisheries)
National scale (per country)
Floodplain (e.g.: lot fishery)
Water bodies (e.g.: refuge ponds)
Habitat patches (e.g. habitat-catches at the fisherman level)

Data sets listed above are more or less relevant depending on the scale considered, and a classification of the scales addressed will allow a better highlight of information gaps.
The resulting assessment of these relationships between fish production and hydrological regimes and related environment should be incorporated into the water management scheme, in order to optimise water allocation in a comprehensive approach.

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