WATER RESOURCE EXPLOITATION OF THE MEKONG RIVER BASIN AND THE INFLUENCES ON THE INLAND FISHERIES OF CAMBODIA

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ABSTRACT

Inland fisheries in the Tonlesap Lake of Cambodia play an essential role in providing with protein and cash income to the poor around the lake. However, the fisheries face a crisis of fish resource depletion due to excessive catch, water pollution and decline in the water level of the Lake. We analyzed the relation of fish catch amounts with the maximum water level in the rainy season and the fish catch in the past, and found that 1% decrease in the water level reduces the catch amounts by 1.25%. What water level can be predicted for the future? To answer this question, we made two models; the one is the water demand-supply model by industry and the other is the water cycle model for the Mekong basin. Depending on various scenarios on the economic development and hydropower dam construction, the reduction in the maximum water level of the Lake would be around 4%, which would lead to a decline in the catch amounts by 5%. In addition to these water quantity issues, we have to consider the inflow of nutrition for which dam constructions would prevent, as well as water pollution of the lake and the excessive catch. Therefore, our estimation on the amount of fish catch reduction in the future is regarded as the conservative minimum one, and the actual catch reduction would be more severe and harmful for livelihoods of the people around the Lake.

**Keywords:** water level, water demand, hydropower dam construction, Dai fishrry

INTRODUCTION

Inland fisheries in the Tonlesap Lake of Cambodia play an essential role in providing with protein and cash income to the poor around it. However, the fisheries face a crisis of fish resource depletion due to excessive catch, water pollution and decline in the water level of the Lake and the Mekong River. Therefore, we try to analyze the relation of fish catch with the water level in the rainy season and the fish catch in the past.

Based on the report by Zalinge *et al* (2003), catch amount of fish by Dai fishery, that is a kind of bagnet fishery located in the Tonlesap River connecting the Lake and the Mekong River, is strongly correlated with the maximum water level of the Lake in the rainy season. It targets migratory white fish leaving the Lake for the Mekong River mainly in November-February. This is because the expansion of the lake provides wider habitats to fish, and Figure 1 presents this correlation. However, this linkage seems to be lost after the year of 2005, and the reason might be a fish resource depletion caused by the excessive catch. The fish resource depletion is supported by the report (Mekong River Commission (2004)) presenting the downsizing trend of caught fish.

Therefore, the purpose of this paper is to identify the influences of the water level and fish catch amount in the past on the current fish catch amount, by applying water demand-supply model which analyzes the influence of water resource exploitation by industrial and urban sectors, and by the water cycle model which analyzes the influence of dam construction for generating electricity in the basin on fish catch through changes in seasonal water flow of the Mekong river, through which the water level of the Lake declines in the rainy season.

Figure 1 Correlation between the Maximum Water Level and the Fish Catch by the Dai Fishery
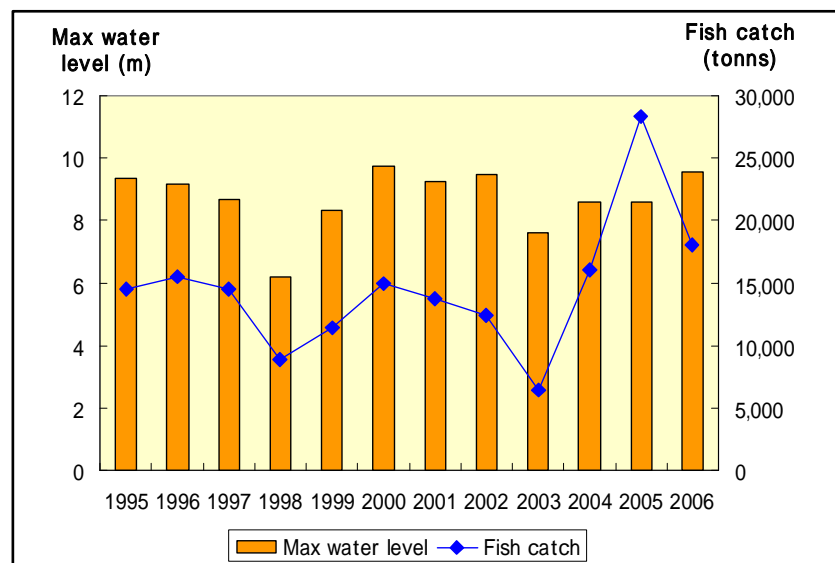
Data source: MRC

DETERMINANT FACTORS OF FISH CATCH

The linkage of water level of the Lake with the fish catch is clear as far as the data before 2004 is concerned. However, a disturbance on the linkage arising from excessive fish catch might have taken place in 2005. Therefore, we try to estimate the linkage witch includes the influence of fishing activities in the past as presented $Q_t = f(WL_t, Q_{t-k})$, where Q_t and WL_t is the fish catch by the Dai fishery in the Tonlesap River and the maximum water level of the Lake in the year of t, and the sign of the coefficient of WL_t and Q_{t-k} is positive and negative, respectively. The estimated result by the ordinary least squares (OLS) is presented as follows;

$$\ln Q_t = 1.253 \ln WL_t \quad 0.703 \ln Q_{t-2} + 13.45 \qquad [\text{Eq. 1}]$$
$$ (1.60) \qquad\quad (-1.94) \qquad\quad (3.22)$$

Period: 1997-2006 $\qquad$ R^2: 0.55 $\qquad$ ( ): t-value.

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The elasticity of current fish catch to the maximum water level is estimated to be 1.25, and that to the fish catch with two years' lag is -0.70, respectively. Considering the equilibrium fish catch level assuming the constant fishing activity every year presented as $Q_t = Q_{t-k}$, the elasticity to the maximum water level is 0.74.

WATER FLOW MODELS AND SIMULATION

The influences of water resource exploitation of the Mekong River are separated into two components. The one is the influence by water demand increase from the industrial and urban sectors. Needless to say, agricultural sector is the dominant water consumer in the region, but the water demand is limited to the dry season which is out of scope in the context of this paper. The agricultural water withdrawal accounts more than 90% of the total water withdrawal except for North East Thailand in the Mekong basin. The other is the influence by changes in the seasonal water flow pattern of the river. If a dam for power generation is operated normally, it would storage water in the rainy season and discharge in the dry season, which would reduce the water flow of the river in the rainy season.

Water demand and water flow of the Mekong River
We consider the influence of water demand growth on the Mekong River water flow. In the early stage of economic development, water resource is mostly used for irrigation, especially for rice production in the dry season in the Mekong basin. However, water demand for industrial and domestic uses has been increasing rapidly accompanied by the economic development. Therefore, we construct a water demand-supply model and estimate the influence of the increase in water demand on the water flow of the Mekong River. The overview of the model is presented in Figure 2, where water supply comes from each country on the monthly basis (Mekong River Commission (2003)) and a certain amount of water is subtracted from the water flow based on the water demand of the each country. Since the analysis is focused on the maximum water level of the Lake in the rainy season, the water demand-supply is limited to water withdrawal for industrial and domestic uses.

Figure 2 Outline of the Water Demand-Supply Model
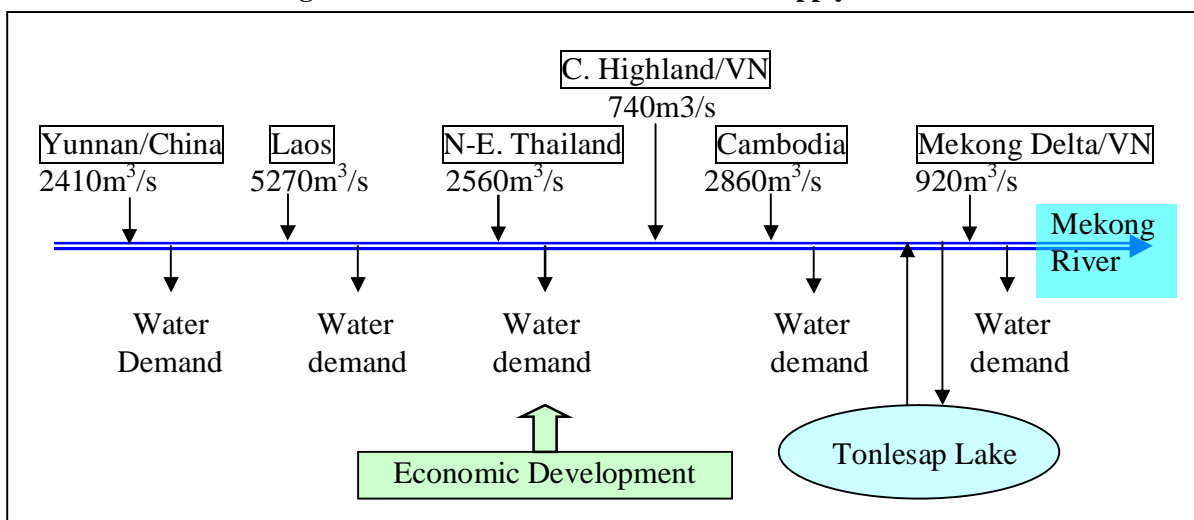
The first step is to analyze the relation of water demand with income level. Figure 3 presents the relation of the industrial water withdrawal with the per capita GDP of manufacturing sector, which covers countries in the Asia-Pacific region in the year of 2000 and a year between 1975 and 1990. In the early stage of industrialization, industrial water withdrawal increases rapidly, but the growth becomes moderate when the economy reaches matured level due to re-locations of water consuming industries and the adoption of water saving technologies. We applied a functional form that has a saturation point at which industrial water withdrawal per capita is maximized at a certain income level, and got an estimated equation as follows;.

$$\ln WATER2 = 4.303 - 112.23 / GDP2 + 719.28 / GDP2^2 \qquad [Eq. 2]$$
$$(13.41) \quad (-4.11) \qquad (2.21)$$

$$R^2 \quad 0.539, \qquad (\quad): \text{t-value},$$

where WATER2 is per capita industrial water withdrawal (m^3/capita), GDP2 is per capita GDP of manufacturing sector of each country ($/capita). Based on the equation, the income elasticity of the industrial water demand is estimated to be 0.64 (Yunnan/China), 1.21 (Laos), 0.98 (North-East Thailand), 1.36 (Cambodia), 1.56 (Mekong Delta/Vietnam), respectively.

Figure 3 Economic Development and the Water Withdrawal

a) Industrial water withdrawal   b) Domestic water withdrawal
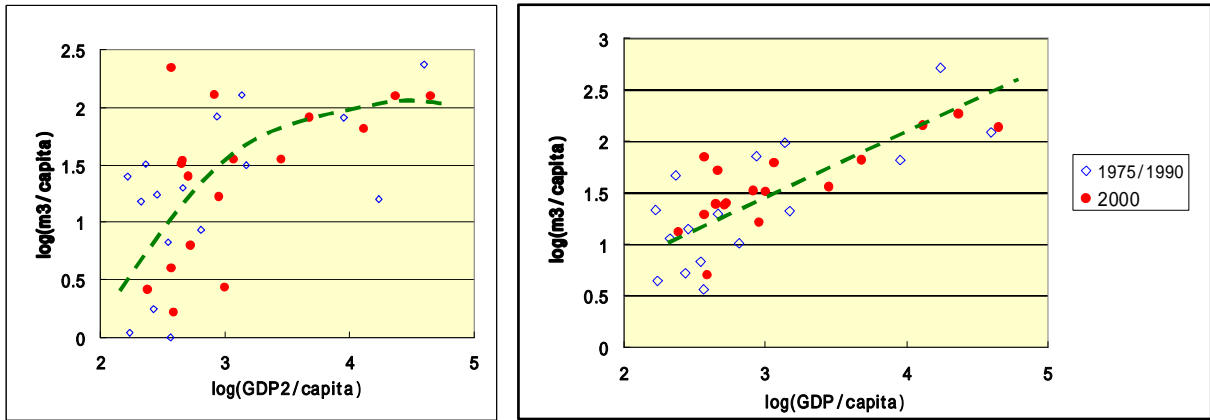
Data Sources: FAO "AQUASTAT" and World Bank "World Development Indicator".
This figure covers Australia, Japan, Korea, China, Vietnam, Cambodia, Laos, Thailand, Malaysia, Indonesia, Philippines, India, Bangladesh, Sri Lanka, Pakistan, Nepal and Bhutan.

For the second step, we estimated the relation of domestic water demand with income level, and the estimated result is presented as follows;

$$\ln (WATER3) = -0.441 + 0.552 \ln (GDP) \qquad [Eq.3]$$
$$(-0.74) \quad (6.65)$$

$$R^2 \quad 0.588, \qquad (\quad): \text{t-value},$$

where WATER3 is the domestic water withdrawal (m^3/capita) and GDP is the per capita GDP ($/capita). Change in the domestic water withdrawal per capita and that of per capita GDP is proportional, and the income elasticity of domestic water demand was estimated to be 0.55.

Then we try to forecast the decrease in water flow in the rainy season in Cambodia caused by the increase in water withdrawal from industrial and domestic sectors. For the purpose, we prepare some scenario on the economic development based on the performance in the past decade. The scenario of "High", "Medium" and "Low" economic growth in terms of the growth rate of per capita GDP is presented in Table 1. As a result, the decreasing ratio of the water flow in the year of 2050 at Cambodia was estimated to be 0.53%, 0.37%, 0.25% for each scenario respectively, implying that the significance of the water used for industrial and domestic sectors would still be limited even if they increase rapidly toward the year 2050.

Table 1 Scenario on the per capita GDP Growth Rate for the Mekong Basin

	China	Laos	Thailand	Cambodia	Vietnam
Low economic growth	5	2	3	3	4
Middle economic growth	7	3	4	4	6
High ecfonomic growth	9	4	5	5	8

Dam construction and water flow of the Mekong River

In order to estimate the influence of dam construction for generating electricity in the upstream areas on the water flow, especially on the water flow seasonal smoothing of the Mekong River, we construct a water cycle model which connects hydrology model to water network model developed by Whenfeng et al (2006). This model can analyze the tidal effects of the Mekong Delta too, while this issue is out of scope of this paper.

We simulate the influence of dam construction based on the Scenario by the World Bank (2004), where dam water storages in China, Laos and Central Highland of Vietnam are assumed to be expanded based on the extension of water resource exploitation as presented in Table 2. In this paper, dams are assumed to be operated to generate electricity throughout a year continuously.

Table 2 Scenario on the Construction of Hydropower Dams
(Active storage volume million cubic meter)

		China	Laos
Baseline	(Case 1)	-	6,185
Low development	(Case 2)	10,300	12,443
High development	(Case 3)	22,700	26,778
High development	(Case 4)[*]	22,700	26,778

Note) Case 4 assumes higher development for irrigation.
Sourcce: World Bank (2004)

As a result, the water flow at Kratie/Cambodia of the Mekong River will decrease by nearly 10% in September for every scenario of Low and High development as presented by Figure 4, and the maximum water level of the Tonlesap Lake will decrease by 34cm (3.9%) in the same month.

Figure 4 Estimation of Water Flow Changes by Hydropower Dam constructions at Kratie
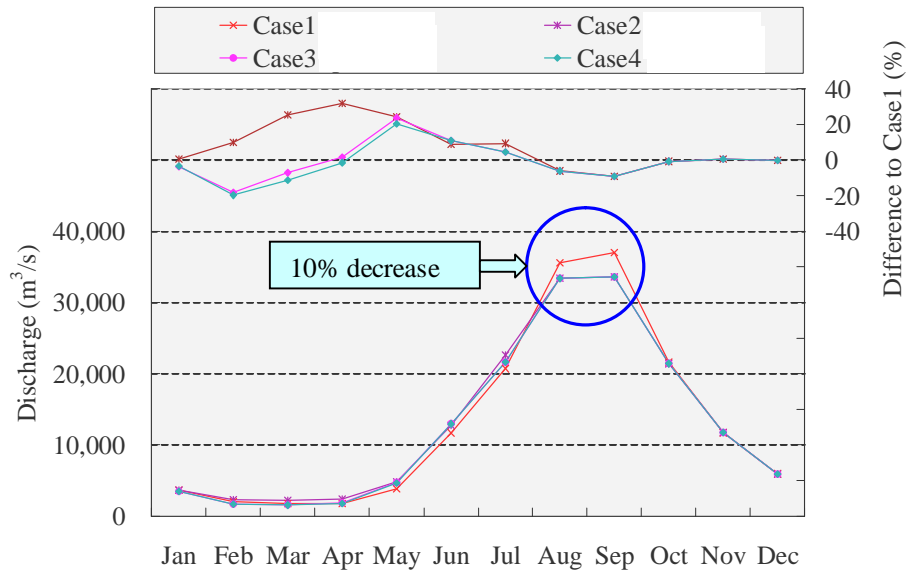
Synthesis

Finally let's consider the total influences by the increase in water demand and by the dam construction. As seen before, the influence by the increase in water demand would be very limited even if we assume a rapid economic growth of this region. Therefore, the influence of the dam construction would be dominant. Then the aggregated influence on the maximum water level of the Lake in the rainy season would be nearly 4%, which would decrease the fish catch by nearly 5% due to the elasticity 1.25.

CONCLUSION

In the Tonlesap Lake of Cambodia, fish resources are decreasing, and the fish catch is determined not only by environmental factors such as the water level of the Lake but also by fishery activities. To analyze the influences by the increasing water demand and dam constructions in the upstream of the Mekong River on the water level of the Lake, we constructed a water demand-supply model and a water cycle model. As a result, it was found that the influence by the water demand from the industrial and urban sectors is not significant since the timing of irrigation water demand is limited to the dry season, and that the influence by the dam construction for generating electricity would decrease the water surface level of the lake in the rainy season by around 3.9%. Then aggregated influences on the water level of the lake would be nearly 4%, which would lead to a decrease in fish catch by 5%.

Bad influences on fish resources are not limited to increasing water demand and dam constructions but include water pollution of the lake and preventive effects for nutrition inflows to the River by dam constructions. Therefore, actual bad influences on fish resources would be more serious than the estimation of this paper. If upstream countries that can export the electricity generated by hydropower dams could compensate for the loss of fisheries in the Tonlesap Lake, promotion of culture fisheries might be an alternative development path of the region.

REFERENCES

Mekong River Commission (2003) "State of the Basin Report", CD-ROM.

Mekong River Commission (2004) "An Introduction to Cambodia's Inland Fisheries", Mekong Development Series No.4.

Wenfeng H., Tanji H., and Kobayashi S. (2006) "Modeling of Hydrological Processing in Lower Mekong Basin: A New Approach to Determine the River Networks", The second International Symposium on Sustainable Development in the Mekong River Basin, Phnom Penh, November, pp.169-176.

World Bank (2004) "Modeled Observations on Development Scenarios in the Lower Mekong Basin", November.

Zalinge N., Loeung D. and Pengbun N. (2003) "Mekong Flood Levels and Tonle Sap Fish Catches", Second International Symposium on the Management of Large Rivers for Fisheries, Phnom Penh, February.