Ecological security & Hydropower dams & Transboundary River

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Abstract

As the developments of cascade dams may lead sever consequences, the ecological security of the river has become the hot issue. The construction and operation of cascade dams on Transboundary Rivers involves bilateral or even multilateral benefits, therefore it is more complex and sensitive. We are working on a variety of approaches that can reduce the ecological risks, guarantee the ecological security of the downstream and help restore the degraded ecological conditions of Lancang-Mekong River. The transboundary effects of flow, sediment, water level and water temperature were analyzed in the paper. At last, a regulation system was put forward to solve the transboundary problems induced by cascade construction. The results in the paper provide a scientific basis for reasonable assessment of transboundary effects of Lancang Cascade on the lower Mekong River.

Keywords

Ecological security, Lancang Cascade, Lancang-Mekong River, LRGR, Transboundary

Introduction

Since few rivers retain their natural state, there has been increasing concern for human impact on river ecosystems over the last few decades (Bockelmann et al., 2004). Dam construction has been considered to be the main driver for the extensive modifications of most river ecosystems. Currently, 2.2% of the world's primary energy production is generated by hydropower installations (Kummu and Varis, 2007). Around 70% of the world's rivers are intercepted by large reservoirs (Kummu and Varis, 2007). The main concerns on the effects of dam construction focus on the change of hydrology, river morphology and habitat.

Dams can change the river’s natural flow pattern and possible increase the flow fluctuation. Since the operation of Hoover Dam and other upstream dams in United States and Mexico, little to no water reached to Colorado’s estuary in the northern Gulf of California (Scho¨ne et al., 2003). The flow regulation will delay the flood arrival and shorter the flooding period (He et al., 2006). As a consequence of dam and reservoir consumption, the water renewal time of the world's rivers has increased dramatically from 20 to 100 d (Golubev, 1993). The self-purification capacity of rivers has decreased a lot.

Lancing-Mekong River region now is facing a huge problem about the ecological security. The direct driving force is the construction of cascade hydropower dams on the mainstream. As an international river, the Lancang Cascade planned on the mainstream of it in China will absolutely have some transboundary effects on downstream countries. In recent years, ecological and socioeconomic issues in Mekong River region have attracted increasing regional and global attention. Much of the concern has been centered on construction of Lancang Hydropower Cascade on the mainstream of Lancang River. It is necessary to analyze the transboundary security of Lancang Cascade and to construct a regulation system to protect and restore the ecosystem.

Methods

Study area

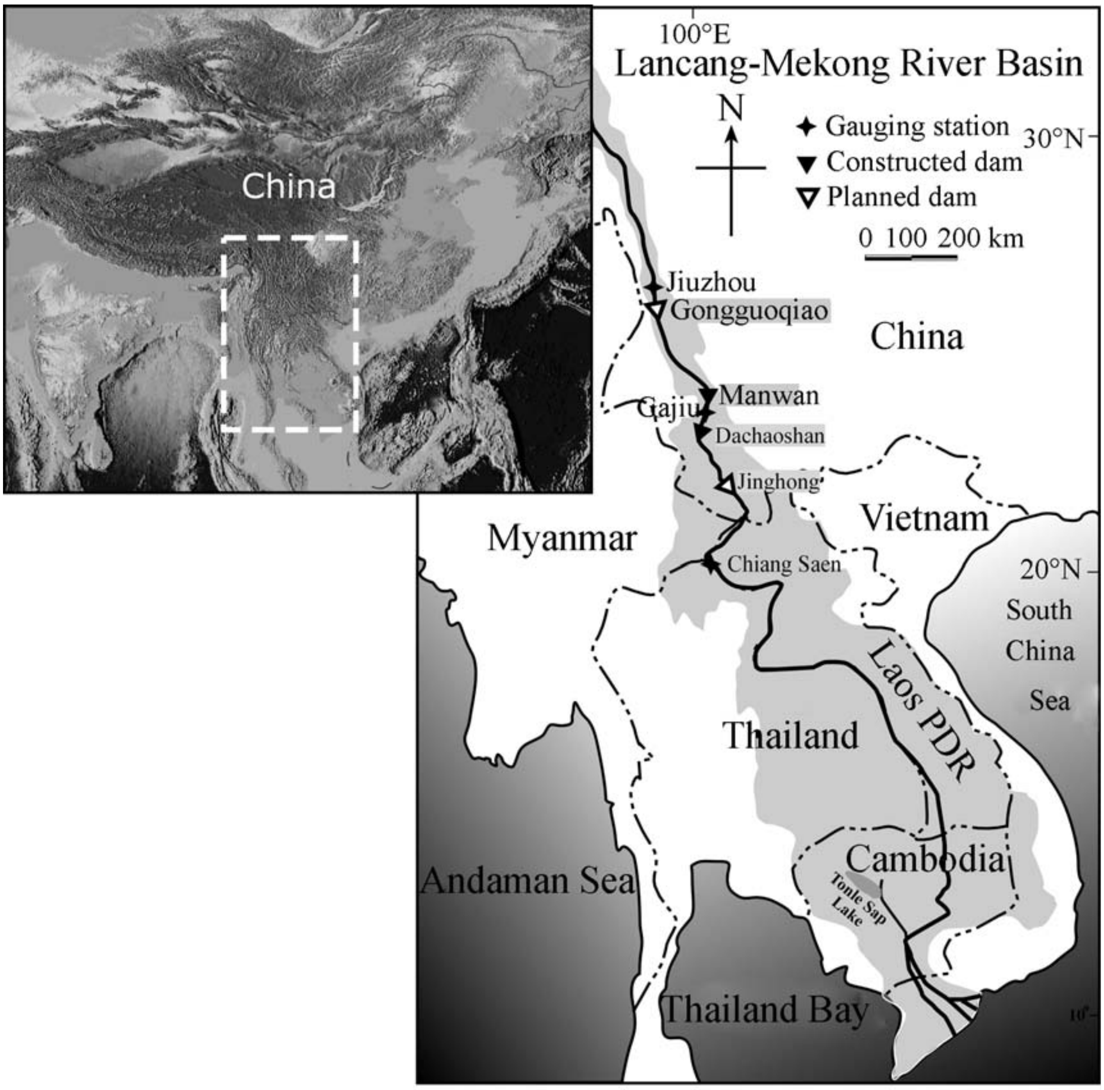

Fig. 1 The Lancang-Mekong River and the relevant dam sites and the gauging stations in the mainstream

Lancang River originates from the Tibetan highlands of China, at an altitude of 4970m above mean seal level. From Tibet, Lancang River crosses the Chinese provinces of Qinghai and Yunnan, and runs through Lao PDR, Thailand, Cambodia, and Vietnam to the South China Sea. As the largest international river in Asia, the whole length of the Lancang-Mekong River is 4880 km. The upper stream of this river in China is called Lancang River and the channel length is 1170 km. It runs through the longitudinal range-gorge area and receives more than 96 branches, covering an area of 90010.03 km^2, and accounting for 23.5% of the Yunnan provincial territory area (Zhang et al, 2007). The lower stream of river outside of China is called Mekong River. The longitudinal direction of this river not only serves as the natural corridor for biological gene amalgamation and human being migration in the north-south direction, but also the natural barrier for biological and human activities in terms of the east-west direction.

In 1980s, the Lancang Cascade in Yunnan, China, a very large engineering project, were proposed. In total, fourteen hydropower dams have been planned from the upstream to the downstream of Lancang River. Among them, eight hydropower dams have been planned in the middle and lower sections. Manwan Dam, the first hydropower dam on Lancang River, was completed in 1993. In 2003, China had completed another dam, Dachaoshan, which is on the downstream of Manwan. Xiaowan Dam, Nuozhadu Dam and Jinghong Dam have been under construction since 2001, 2006 and 2005, respectively. The scale of the Lancang Cascade is very large. Xiaowan and Nuozhadu Dam are the two largest dams on Lancang River. Ganlanba and Mengsong Dam are two smallest dams without storages in the lowest of Lancang River.

Yunjinghong station is the last national basal gauging station before Lancang River flows out of China. Chiang Saen gauging station is the first gauging station on the mainstream of the Lower Mekong River.

Data and statistics

The research for this article was based on observed monthly flow data from the three mainstream hydrological stations located at Jiuzhou (above the Manwan Dam), Gajiu (below Dachaoshan Dam) and Yunjinghong in Yunnan for the period of 1956-2001. Together with observed data from stations on the Lower Mekong from the 1950s onward, these data were used to analyze spatial and historical patterns of changes in flows throughout the upper and lower Lancang-Mekong watershed. A wavelet analysis of monthly precipitation data in Yunnan over the period of 1951-2002 permits exploration of the linkages between changes in flow volumes and regional climate change.

Observed daily water level data at the Yunjinghong stations (1987-2003) and Chiang Saen gauging station (1986-2004) were used as the data. Binomial coefficient weighted average method, five-year moving average method were used to analyze the spatial and temporal correlations, the interannual and interdecadal variations of Lancang-Mekong River.

The sediment data series from 1987 to 2003 at Yunjinghong and Chiang Saen stations in the mainstream of the Lancang-Mekong River are used to reveal the impacts caused by the Lancang cascade. Monthly mean sediment concentration data of the two stations are compared and yearly series are analyzed by the method of correlation and regression analysis and causality test.

Water temperature data of Yunjinghong station (1985-2001) and Chiang Saen station (1985-2001) were used to do the comparison analysis to discuss the relationships between the two stations.

Results

Flow (He et al., 2006)

The two existing dams of Manwan and Dachaoshan are but one of the many factors influencing the flows of Mekong River, not a major factor. Significant downstream impacts of the two existing dams are limited in scale to changes in daily flow stages, and are limited geographically to the narrow channel north of Vientiane. Over timescales of several days or more, the primary factor in flow changes is climate change. Below the Yunjinghong hydrologic station, low volumes can be as great as $113.7\times10^8 m^3$, or 15.44% of the average annual total runoff out of China, now are not influenced by the dam construction. The results of a simulation based on the period form 1953 to 1993 of annual flow data analyzing the flow regulation effects of the construction periods of Manwan, Dachaoshan, Jinghong and Xiaowan on monthly flow allocation for Lancang outflow into the lower Mekong are shown in Figure 2.

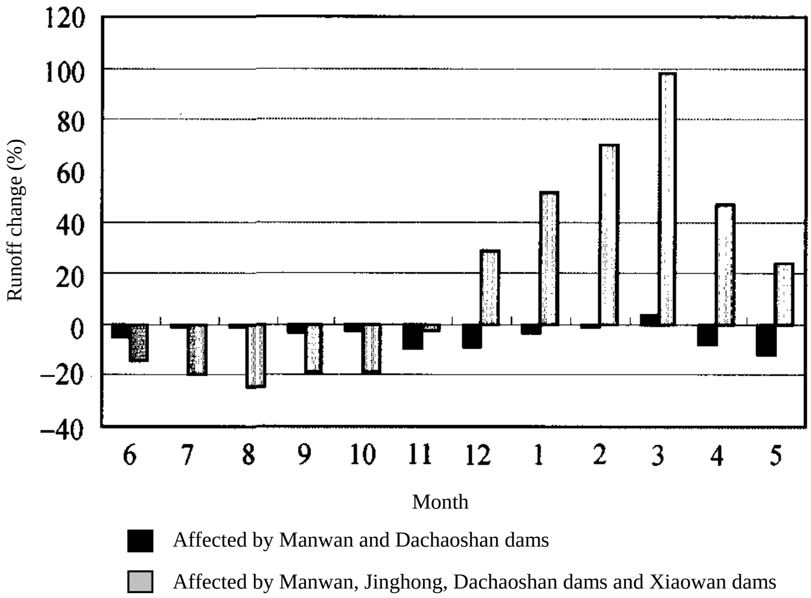

Fig.2 The effects of cascade development at different phases on downstream monthly runoff allocation.

Sediment (Fu et al., 2006)

The sediment response of the Yunjinghong and Chiang Saen stations are different under the regulation of the hydropower stations. Annual series at Yunjinghong station are positively correlated but do not match well with those at Chiang Saen station (Fig. 3). In addition, the results of Granger causality test on the time series also suggest that the series of maximum monthly mean sediment concentration of the Yunjinghong station each year may give cause for the ones of Chiang Saen station, while the series of minimum monthly mean sediment concentration of Yunjinghong do not evidently give cause for the ones of the other station.

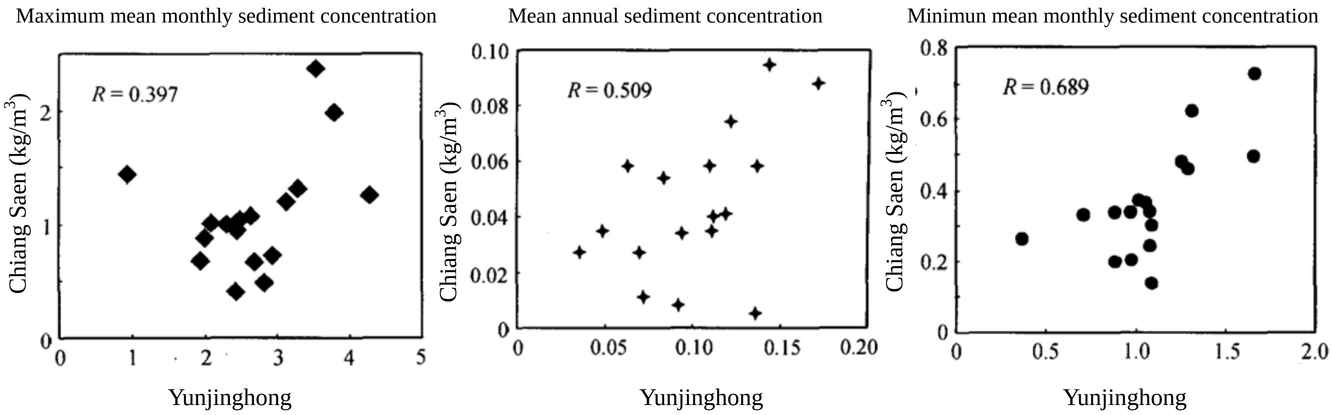

Fig. 3 Regression scatters points of the sediment concentration in each year at Yunjinghong and Chiang Saen hydrological stations.

Water level (Li et al., 2006)

The annual variations of water level in Lancang River exhibit multi-timescale characteristics. And positive correlations are observed between the multi-timescale variations of the Lancang River water level in upper reaches. Annual variations of the water level in upper-lower reaches exhibit prominent interannual and interdecadal features (Fig. 4s), during the recent 18 years, while differences mainly happen to the smaller time-scales. That shows the water level annual variations at both stations are influenced by the climatic factors and solar activity. The normal operation of cascade hydropower dams in the main upstream of Lancang River has some interim effects on downstream monthly or yearly water level. It may have more impacts on short-term daily water level, such as of few day's variations. It also can be found that the individual monthly-high water level between tow stations show prominent positive correlation, as well as the dates of that. But as for as the multi-timescale correlations of water level in Lancang and Lower Mekong River is concerned, the major causes of considerable differences in water level variations are attributed to both runoff flowing from the upstream (the Lancang River) and he high local inflow between two stations.

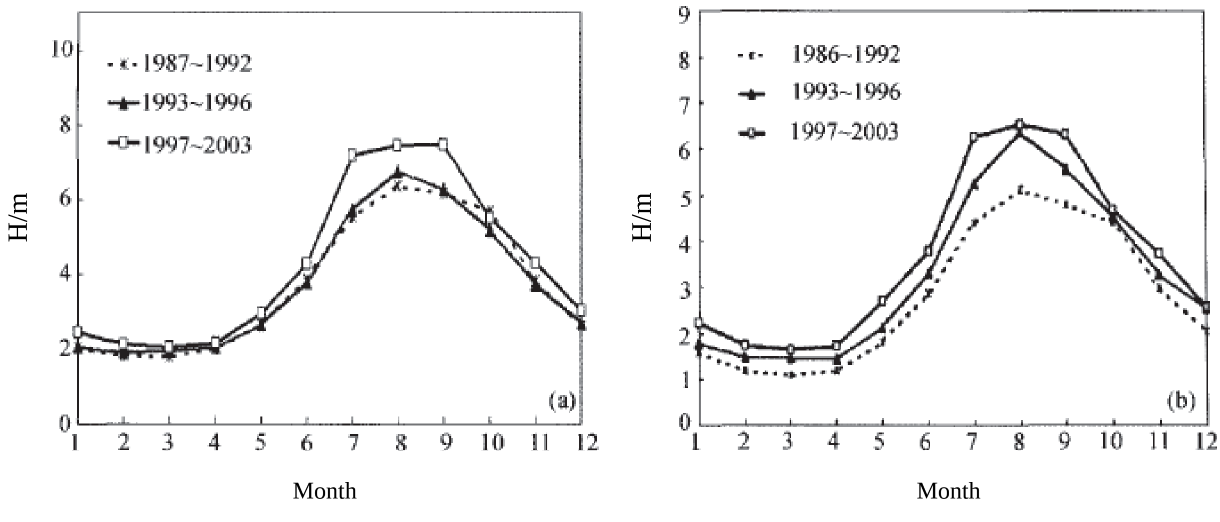

Fig. 4 Intra-annual allocations of monthly water level (H). (a) Yunjinghong station; (b) Chiang Saen station.

Water temperature (Zhang et al., 2007)

Water temperature was higher in the lower part of the river continuum than the upper part. Latitude variation is the main influencing factor. This effect is more obvious in dry season than in rainy season, more obvious in winter than in summer, and more obvious of the average minimum WT than the average maximum WT. WT difference between the upper and the lower parts of the river continuum was decreasing due to little increase of WT in the upper part (Yunjinghong hydrological station) and obvious decrease of the WT in the lower part (Chiang Saen hydrological station) during the research period (Fig. 5). Therefore, the parameters of WT are affected by the latitude, and the Lancang-Mekong river continuum lies in the north-south direction, so the tropical aquatic creatures, such as the tropical aquatic fishes, cannot survive in the upper part of this river continuum in winter season, while in summer season, the tropical aquatic creatures properly swim to the upper stream. The water temperature in the lower Mekong River is mainly influenced by the regional water temperature and regional climate change.

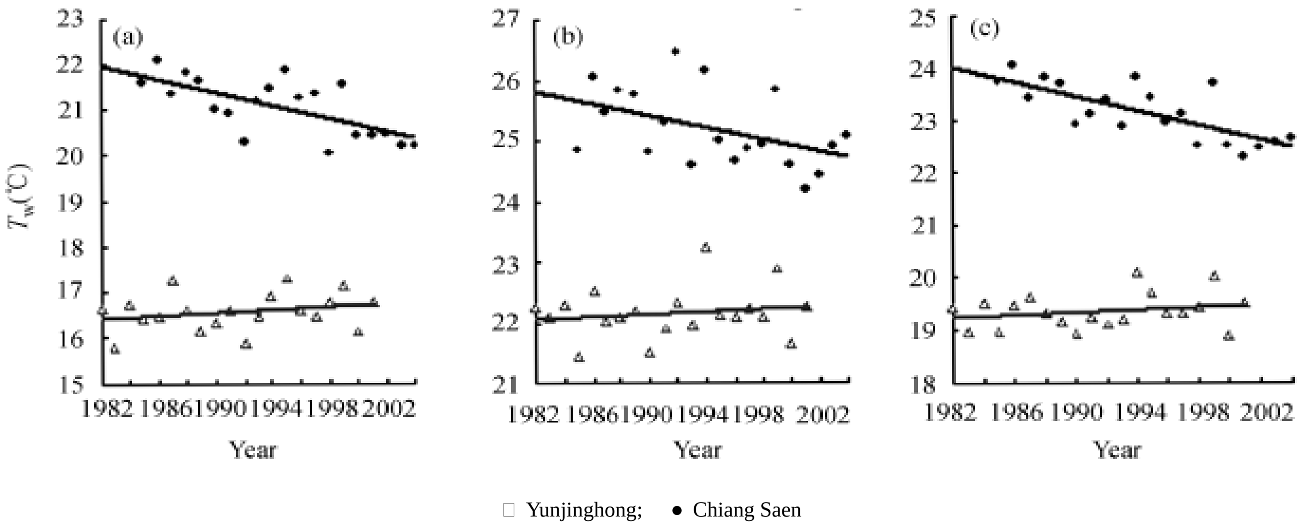

Fig. 5 Time series for average water temperature difference between Yunjinghong (open triangles) and Chiang Saen (dots) hydro-stations from 1985 to 2001. (a) Dry season; (b) rainy season; (c) yearly.

Framework for ecological transboundary security regulation

The downstream socioeconomic and environmental impacts and interactions resulting form the construction of large dams are extremely complex and cannot be classified simply as positive or negative (He et al., 2006). In the case of large dam construction on international rivers, the situation becomes even more complex sue to political sensitivity and limitations of data accessibility that make comprehensive assessments difficulty (Feng et al, 2006; He et al., 2006).

A regulation framework for transboundary security in LRGR was constructed (Fig. 6). The first step in the regulation framework is to find the main problems about the transboundary security. The problems may contain downstream flow decrease, water pollution, sediment decrease or barriers for the migratory fish. After the determination of the main problems, the next step is to analyze these problems. The main driving forces, the characteristics of the problems, the negative and positive effects of the dam construction and the distribution patterns of the problems are analyzed deeply. The last step is to solve the problems. The transboundary problems are complex and sensitive. They are difficult to solve. The most important tasks to deal with the transboundary issues in the LRGR are to form internationally participative cooperation mechanism, establish fund for transboundary eco-security, implement ecological compensation strategy, and develop information exchange platform and warning system as well as policy and law system (He et al., 2006).

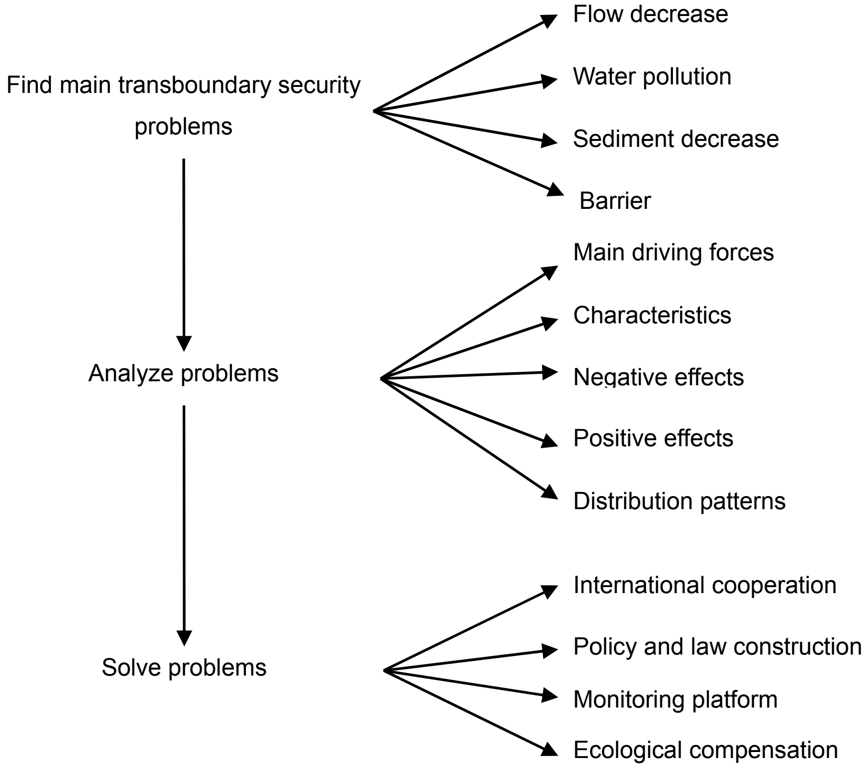

Fig.6 Regulation framework for transboundary security in LRGR

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References

Bockelmann B N, Fenrich EK, Lin B, Falconer RA. Development of an ecohydraulics model for stream and river restoration. Ecological Enginerring, 2004, 22, 227-235.

Cui B S, Zhai H J. 2008. Quality evaluation of habitats disturbed by the Manwan Hydropower Dam (In Chinese). Acta Scientiae Cireumstantiae, 28(2): 227-234.

Feng Y. He D M, Gan S, Gu Y. Linkages of transboundary water allocation and its eco-thresholds with international laws. Chinese Science Bulletin, 2006, 51 (z2): 25-32.

Fu K D, He D M. Analysis and prediction of sediment trapping efficiencies of the reservoirs in the mainstream of the Lancang River. Chinese Science Bulletin, 2007, 52 (z2): 134-140.

Golubev G. Sustainable water development: implications for the future. Water Resources Development, 1993, 9 (2): 127-154.

He D M, Liu J, Hu J M, Feng Y, Gan S. Transboundary eco-security and its regulation system in the Longitudinal Range-Gorge Region. Chinese Science Bulletin, 2007, 52 (z2): 1-9.

Kummu, M., Varis, O. Sediment-related impacts due to upstream reservoir trapping, the Lower Mekong River. Geomorphology, 2007, 85: 275-293.

Li S J, He D M, Fu K D. the correlations of multi-timescale characteristics of water level processes

in Lancang-Mekong River. Chinese Science Bulletin, 2006, 51 (z2): 50-58.
Scho¨ne B R, Flessa K W., Dettman D L., Goodwin D H. Upstream dams and downstream clams: growth rates of bivalve mollusks unveil impact of river management on estuarine ecosystems (Colorado River Delta, Mexico). Estuarine, Coastal and Shelf Science, 2003, 58: 715-726.
Zhai H J, Cui B S, Wang Y, Wang J, Zhao X S, Hu B. 2008. Ecosystem sustainability assessment of Yilong Lake wetland and time—lag effects analysis of the PSR model (in Chinese). Acta Seientiae Cireumstantiae, 28(2): 243-252.
Zhang Y P, Gao F, He D M, Li S H. Comparison of spatial-temporal distribution characteristics of water temperatures between Lancang River and Mekong River. Chinese Science Bulletin, 2007, 52 (z2): 141-147.