Xiaowan Dam

Environmental and Social Impacts of Lancang Dams

Summary

This research brief focuses on the downstream impacts on hydrology, fisheries and sedimentations caused by the Lower Lancang cascade in China. Manwan and Dachaoshan were the first two dams completed on the Lancang River (in 1995 (first phase) and 2003 respectively) and many changes have been observed. Many scientific studies have been done to evaluate the impacts from Manwan and Dachaoshan dams by analyzing monitoring and survey data. With the two biggest dams of the cascade, Xiaowan and Nuozhadu, put into operation in 2010 and 2012, bigger downstream impacts are expected to be observed.

In the wet season (May to October), the Lancang dams run at normal operation levels for power generation and release extra water if the water level exceeds normal water level. In the dry season (November to April), when the inflow is not enough, Xiaowan and Nuozhadu will generally release the water to downstream dams so as to ensure other dams can run at full capacity. Xiaowan and Nuozhadu are the two yearly regulated dams with big regulation storages, while all the others have very limited seasonal regulation capacity.

A wide range of studies have confirmed that the wet season flow will decrease, while the dry season flow will increase because of the operation of the Lancang dams. Because the Lancang river contributes 45% of water to the Mekong basin in the dry season, the flow change impacts on downstream reaches will be more obvious increasing flows by over 100% at Chiang Saen. An increase in water levels in the dry season will reduce the exposed riverbank areas for river bank gardens and other seasonal agriculture. Millions of villagers who live along the Mekong River grow vegetables in riverbank gardens and their livelihoods will be largely impacted if losing the gardens. In the wet season, the decrease of flow at Chiang Saen caused by the Lancang dams holding back water to fill storage and regulation reservoirs is about 30%. Such decrease will cause the reduction of floodplain area and the flow of nutrients from floodwaters deposited on flood plains.

The Lancang Dams have also altered the water temperature. The daily average water temperature at Chiang Saen

decreased after Dachaoshan Dam started operation. The water temperature fluctuation range within a year at Chiang Saen has also increased. Once the Lancang dams in the middle reaches are constructed and start operation, the temperature impacts brought by the Lancang dams are certain to accumulate and extend at lease hundreds of kilometers downstream. The decrease of water temperature and the enlarged water temperature fluctuation will change the behaviors of the fish species, impacting their reproduction and migration activities. The composition of algae and microorganism, which form the foundation of the food chain in the aquatic ecosystem, may also change.

The dams not only change the flow and temperature but also block fish migration channels, which are both important for reproduction. The extent of fish migration from the Lower Mekong into the Upper Mekong is unknown. *Pangasius*, however, have been found to forage and spawn in the Buyuan River, a tributary of Lancang River between Jinghong and Mengsong Dams. Other fish species such as *Tor sinensis, Wallago attu, Hemibagrus wychioides* may also migrate between the Lower and Upper Mekong. Without baseline data, it is now very difficult to evaluate the impacts of the existing six dams on long distance migration fish species between the Lower and Upper Mekong.

Much larger local impacts on fishes and fisheries have been caused by the Lancang Dams. Changes in local fish species both in number and composition have been observed since the Manwan Dam was built. Demersal fishes, which are more adapted to fast flowing conditions and the fish species which live in the middle and bottom layers of flowing water have been greatly decreased due to loss of habitat, reproduction areas and food availability. The number of large sized fish has also decreased, while middle and small sized fishes have become the dominant species. Due to local aquaculture on or around the Lancang, a mix of native and alien fishes can now be found in reservoir areas. Some alien fish species have become dominant species resulting in a decrease of local fish species. With six dams completed, most of the middle and lower reaches of Lancang River has been turned from a running river into a series of reservoirs. In the future, researchers expect to see more significant changes in the number and composition of fish species in the middle and lower Lancang River.

Several scientific reports have found that half of the sedimentation in Lower Mekong originates from the Lancang basin, which is about $80*10^6$t/yr. Because of the different measuring methodologies used between Yunnan and downstream Mekong countries, as well as different analysis methodologies, the sedimentation capture rate by the Manwan Dam has been estimated in a range of 53% to 94%.

> In the first ten years of Manwan Dam's operation, the annual mean sediment trapped by the Manwan Dam was estimated to be about 35% of total sedimentation transported from Lancang Basin to Lower Mekong. There is no trend of reduction in sediment trapped in the ten years since Manwan began operation.

The reduction of sedimentation downstream not only can result in riverbank erosion, but also reduces the nutrients carried in the flow and deposited in fertile flood plain areas, which is the base of the ecosystem. It may also trigger acceleration of seawater intrusion in the delta area. These impacts aren't easily observed in a short term, but accumulate over the long-term. As some researchers reported, the sedimentation impacts from Manwan Dam extends as far as Vientiane on the Mekong River in Laos. Manwan is just one of the four relatively smaller dams in the Lower Lancang and there are another two huge dams which are three times bigger than Manwan in terms of capacity and dam height. With the operation of all the six dams, the reduction of sedimentation flowing downstream will only increase and its impacts more obvious and extending further downstream.

All of these changes in hydrology, fisheries and sedimentation caused by the Lancang dams are not only changing the river, they also have extensive and more significant impacts on millions of people who rely directly on the river for their food and livelihoods. Fish are the main source of protein for many people throughout the region. The hydrological and sedimentation schemes are fundamental for the habitat where fish live and reproduce. Altering the hydrological and sedimentation schemes and blocking fish migration will potentially cause the reduction of fisheries and change of fish composition in the Mekong River, and lead to food security and livelihood risks. Furthermore, the reduction of sedimentation deposit and the seawater intrusion will affect the highly productive agricultural and rice fields in the region, which depend on the nutrients that the Mekong River transports in its sediment, and therefore create even bigger challenges in food and livelihoods

1. Background

China has planned 28 hydropower dams on the Lancang River, which crosses through Qinghai, Tibet and Yunnan before flowing into Myanmar, Laos, Thailand, Cambodia and Vietnam. Six hydropower dams have been completed on the Lower Lancang River in Yunnan, including Gongguoqiao, Xiaowan, Manwan, Dachaoshan, Nuozhadu and Jinghong. The lowest dam on the Lower Lancang dam cascade, Mengsong has been cancelled, but the second lowest dam Ganlanba is still planned. Additionally, there are another 7 dams, either under site preparation or under construction, on the Middle Lancang and another 14 dams planned on the Upper Lancang, one of which has already been completed. Detail information of dams and hydrological stations on the Lower Lancang can be found in the Table 1 and the locations of dams are as shown in Figure 1. Table 2 lists the hydrological stations along the Lancang River. China agreed to release the hydrological data from Jinghong station and Manwan Station (which is on the Buyuan River, a tributary of Lancang) to the Mekong River Commisision during flood season.

Table 1: Dams in the Lancang Hydroelectric Cascade within Yunnan

Dam Name	Installed Capacity (MW)	Dam Height (m)	Total Storage (km^3)	Regulation storage (km^3)	Regulation Type	Status
Gongguoqiao	900	130	0.32	0.05	Seasonal	Completed (2012)
Xiaowan	4200	292	15	10	Yearly	Completed (2010)
Manwan	1550	126	0.92	0.26	Seasonal	Completed ((phase 1 in1995 and phase 2 in 2007)
Dachaoshan	1350	118	0.94	0.36	Seasonal	Completed (2003)
Nuozhadu	5850	261.5	22.7	11.3	Yearly	Completed (2012)
Jinghong	1750	118	1.14	0.23	Seasonal	Completed (2009)
Ganlanba	155	60.5			Run-of-river	Planned

Figure 1. Map of Lancang River Dams

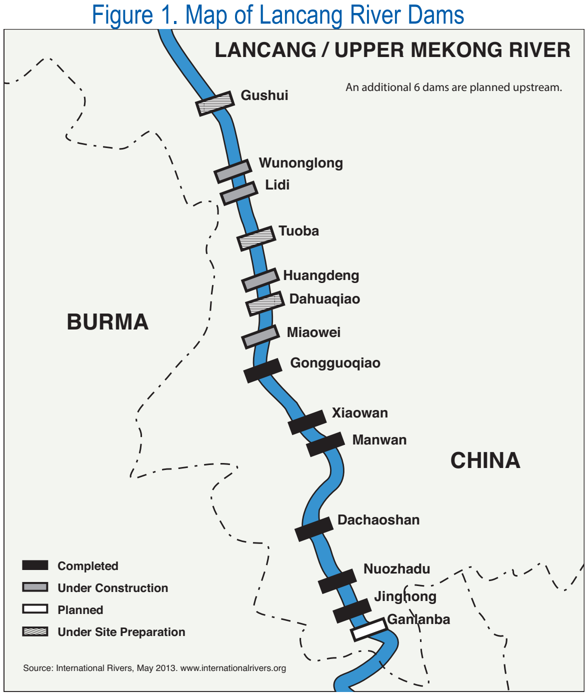


Table 2. Stations along the Lancang River[1]

Station	Catchment area (km^2)	Extreme discharge (m^3/s) max	Extreme discharge (m^3/s) min	Mean annual discharge (m^3/s)	Mean annual flow (Mm^3)
Changdu	53800	3890	60	487	15400
Liutongliang	76690	4600	161	802	25300
Jiuzhou	87205	6360	206	935	29500
Gajiu	107681	8840	275	1220	38420
Jinghong	140933	12800	395	1870	58900
Border	167487				73630

1. Plinston, D. and H. Daming. 2000. Water Resources and Hydropower in the Lancang River Basin, Landcare Research New Zealand Ltd. ADB TA 3139: PRC, Policies and Strategies for Sustainable Development of the Lancang River Basin, Chapter 4: Water Resources and Hydropower.

2. Hydrology

2.1 Flow and water level

Although the Lancang River flow only contributes 16% of the overall average of the Mekong River Basin's flow (Figure 2)[2], the Lancang still provides a significant amount of the water flow to Laos. Almost 80% of the Mekong River's water at Vientiane comes from China in the dry season, and at the height of the dry season in April the contribution of Lancang is still 40% of the flow at Kratie in Cambodia (Figure 3).[3]

Figure 2 Overall average contribution to the runoff of the riparian countries in Lancang-Mekong basin (%)[4]

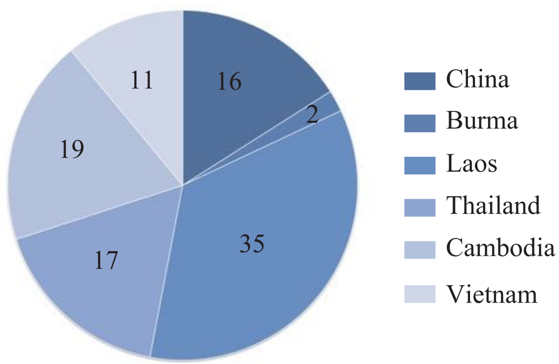
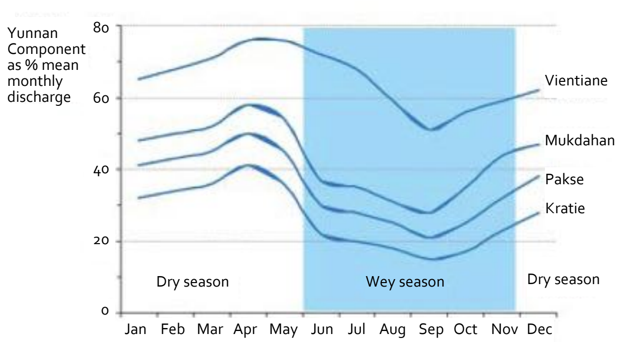
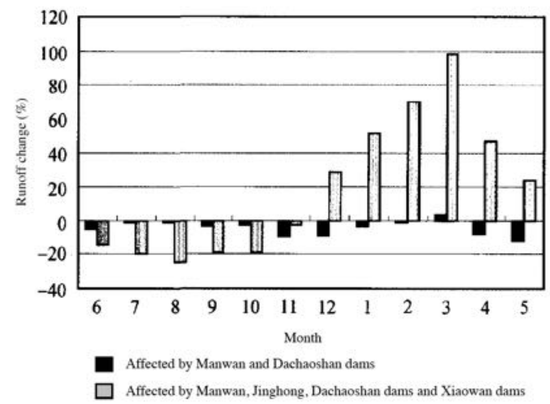


Figure 3 Mekong mainstream percentage contribuition of the Yunnan Component to mean monthly flow at selected sites[5]



It has been widely recognized that the construction and operation of Lancang dams has increased dry season flows and reduced wet season flows. Chinese researchers[6] estimate that flows at China border due to Manwan, Daochaoshan, Jinghong and Xiaowan dams, will increase the most and by as much as 100% of the average monthly flow in March (Figure 4).

Figure 4 The impacts of Lancang hydropower cascade on the discharges at China border[7]



Rasanen (2012)[8] found that on average the Lower Lancang cascade (excluding Ganlanba) increased the December–May discharge by 34 – 155 % and decreased the July–September discharge by 29 – 36 % at Chiang Saen station in Thailand (Figure 5). The Lancang cascade has reduced the range of hydrological flow variability by 29 - 73% in the wet season (May – September) but increased significantly the hydrological variability by 88% to over 300% during the dry season (January to April).

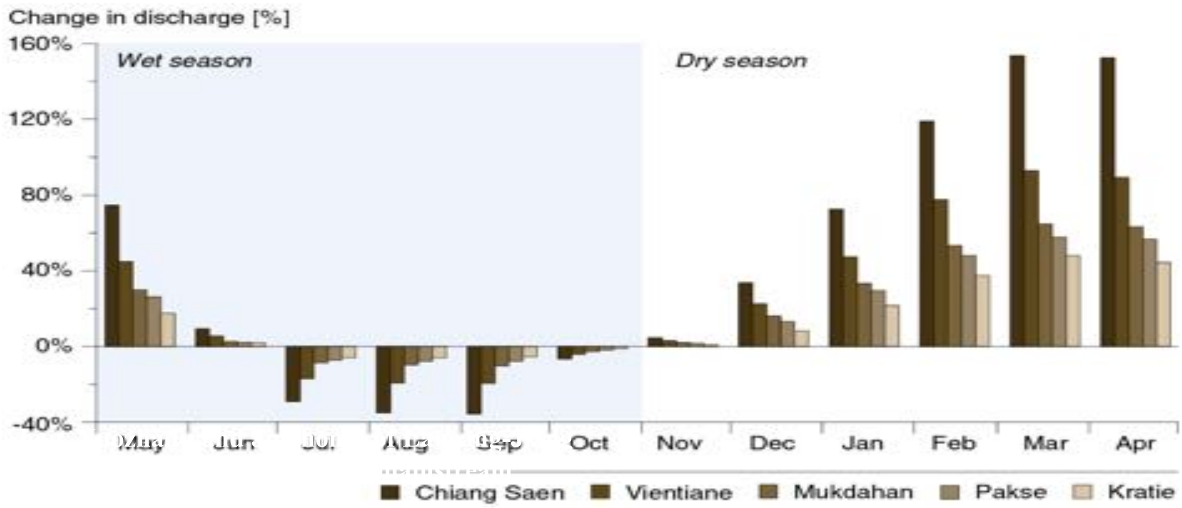
The average monthly flow changes are greater in the dry season months and largest in March and April. The study also found that the impacts extend as far as Kratie in Cambodia, especially in the dry season. The biggest change in average monthly flows in Kratie was by 49% in March, which corresponds approximately to a 1.1m increase in the average monthly water level.

Some other studies which used different modeling methodologies but the results all show similar trend of increased

2. Chen L., He D. 2000. The Ecological Impacts of Hydropower Cascade Development in Lancang-Mekong River, Journal of Geographical Science Vol 55, No.5: 577-586.
3. Mekong River Commission. 2005. Overview of the Hydrology of the Mekong Basin. ISSN: 1728 3248.
4. See No. 2
5. See No. 3

6. See No. 2
7. See No. 2
8. Rasanen T., et al. 2012. Downstream Hydrological Impacts of Hydropower Development in the Upper Mekong Basin. Water Resources Management 26: 3495-3515.

Figure 5 Monthly average flow changes (%) caused by the 6 dams scenario (Gongguoqiao, Xiaowan, Manwan, Dachaoshan, Nuozhadu and Jinghong) of Lancang-Jiang cascade at five locations in the Mekong mainstream[9]



flows during the dry season.[10, 11] Adamson's analysis showed that at Kratie station in Cambodia, the dry season flow could increase by up to 20% on average and by up to 50% during March and April.[12] Chapman and Daming (1996) reported that during the mean dry season the flow at the tri-border area (China, Laos and Myanmar) can increase by 40% with Xiaowan and as much as 170% with Nuozhadu operating and regulating the flow of water and hydropower generated by the lower cascade. [13]

We found a close relationship between the average monthly water change at Chiang Khong hydrological station and the filling of Nuozhadu Dam (Figure 6). Nuozhadu Dam's filling was completed in three stages: the first and second stages started in November 2011 and were finished in July 2012, and the third stage started in June 2013 and was finished in October 2013. Figure 6 shows sudden changes in these time periods caused by the filling. In the future, because the Nuozhadu and Xiaowan dams will release water to regulate the rest of dams in the cascade to ensure their power generation capacities, the Nuozhadu and Xiaowan dams will face the biggest challenges in terms of water quantity by the end of the dry season and have to refill the reservoirs in the beginning of wet season at a desirable speed. Therefore, we would expect similar sudden changes to happen repeatedly every year. The total regulation capacity of the cascade is about equal to the Nuozhadu Dam's reservoir storage capacity. Delayed wet season and longer dry season should be expected, especially in the dry years.

Since Manwan and Dachaoshan started operation, the changes of flow and water levels can be found by analyzing monitoring data. Zhong (2007) examined the 1962-2003 monitoring data at Chiang Saen station and found that after the Manwan Dam was built, the yearly average minimum flow decreased from 752m^3/s to 569m^3/s, which represents a reduction of around 25%. [14] Xue (2011) found that the runoff at Pakse in Lao PDR became more dependent on regional precipitation once Lancang dam building had begun. As the number of dams on the Lancang River increases, river runoff will rely more on regional precipitation because the dams and reservoirs will minimize the variation of upstream inflow.[15]

Based on the 1996—2002 water level data from Jiuzhou, Gaojiu and Yunjinghong stations, little impact has been found on the annual high water level by Manwan and Dachaoshan Dams. However, the water level data from Jiajiu and Yongjinhong hydrological stations show that the lowest water levels in 1993-2002 (recorded each year)

9. See No. 8
10. Adamson P. 2001. The Potential Impacts of Hydropower Developments in Yunnan on the hydrology of the lower Mekong. International Water Power and Dam Construction 53:16-21.
11. Hoanh C. et al. 2010. Impacts of Climate Change and Development on the Mekong Flow Region, First Assessment – 2009. MRC Technical Paper No. 29 Mekong River Commission, Vientiane, Lao PRD.
12. See No. 10
13. Chapman E. and He D. 1996. Downstream Implications of China's Dams on the Lancang Jiang (Upper Mekong) and their Potential Significance for Greater Regional Cooperation Basin- Wide, Monash Asia Institute, Australia.
14. Zhong H. et al. 2007. Cumulative Effects of Lancang River Basin Cascade Hydropower Development on Ecology and Environment. Journal of Hydraulic Engineering Supplemental Issue: 577-581.
15. Xue Z., Liu J., and Ge Q. 2011. Changes in Hydrology and Sediment Delivery of the Mekong River in the last 5 Years: Connection to Damming, Monsoon, and ENSO, Earth Surface Processes and Landforms, 36: 296-308.

Figure 6: Relationship between monthly water level at Chiang Khong and Nuozhadu Dam's filling

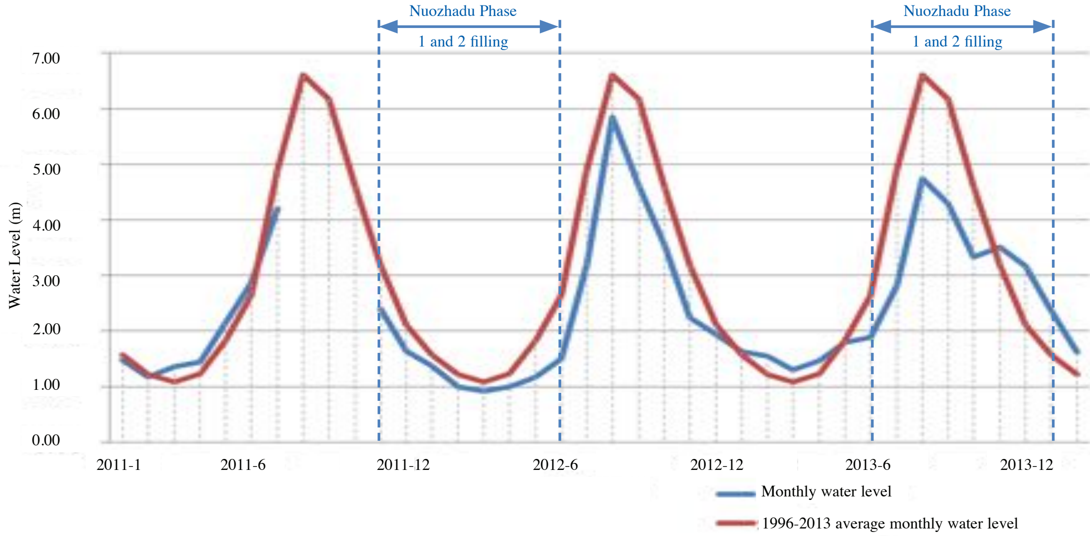
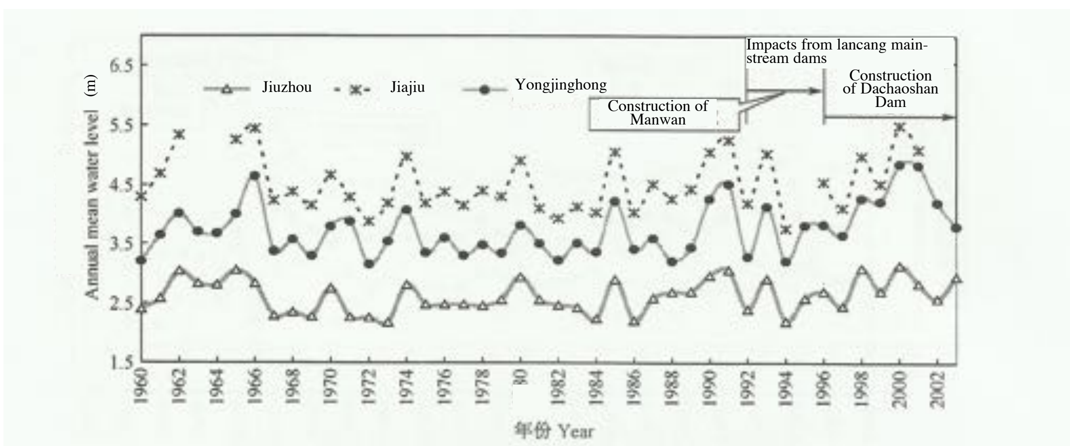


Figure 7 Change of annual minimum water levels at 3 stations on the Lancang mainstream[16]



were much lower than that in pre-dam years. The biggest decreases in annual lowest water levels were found at Jiajiu (figure 7).[17]

Another hydrological consequence from the Lancang dams is an increase in evaporative water loss. A study estimated that after the eight cascade dams (including the cancelled Mengsong) on the middle and lower Lancang are built, the total surface water area will be seven times bigger than the pre-dam natural water area, which would increase the evaporation by 0.22 billion cubic meters per year. [18] However, the increased evaporation makes up less than 1% of the total runoff recorded at Yunjinghong station, therefore the downstream impact caused by evaporative water loss is minimal.

16. He D., et al 2009. 纵向岭谷区跨境生态安全与综合调控体系.
17. See No. 16
18. See No. 14

2.2 Water Temperature and Water Quality

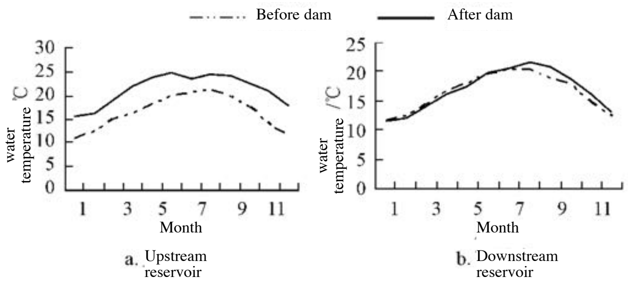
Due to the transformation of the river to a series of reservoir, reservoir surface water temperature during every month in post-dam period is much higher than in pre-dam period. The average temperature in Manwan in post-dam period was 4.8 degrees higher than that in pre-dam period. (Figure 8)[19]

After Manwan started operation, the water temperature at Jiuzhou and Yunjinghong stations showed an obvious positive corresponding relationship, which means the Manwan Dam has caused changes of water temperature as far as at Yunjinghong station, 401km downstream.[20] With the bigger

19 Li X., et al. 2010. Impacts of Manwan Dam Construction on Aquatic Habitat and Community in Middle Reach of Lancang River. Procedia Environmental Sciences, 2: 706-712.
20. See No. 16

dams Xiaowan and Nuozhadu, the cumulative water temperature change will become more prominent.

Figure 8 The monthly temperature of surface water temperature at upstream and downstream before and after the construction of Manwan Dam[21]



The water in a deep reservoir stratifies with a large volume of cold, oxygen poor water. The water released by large dams is usually from the colder layer of the water in the reservoir, resulting in lower water temperatures compared with the temperatures recorded prior to dam construction. The temperature change is far reaching with the change caused by Manwan being felt 401 km from Yunjinghong station.[22] The daily average water temperature data collected at Chiang Saen also shows an obvious decrease after Dachaoshan Dam started operation. The water temperature fluctuation within a year at Chiang Saen has also increased, especially in the dry season January – April (Figure 9). [23]

Figure 9 Water temperature in some typical days of each month at Chiang Saen site (1985-2001)[24]

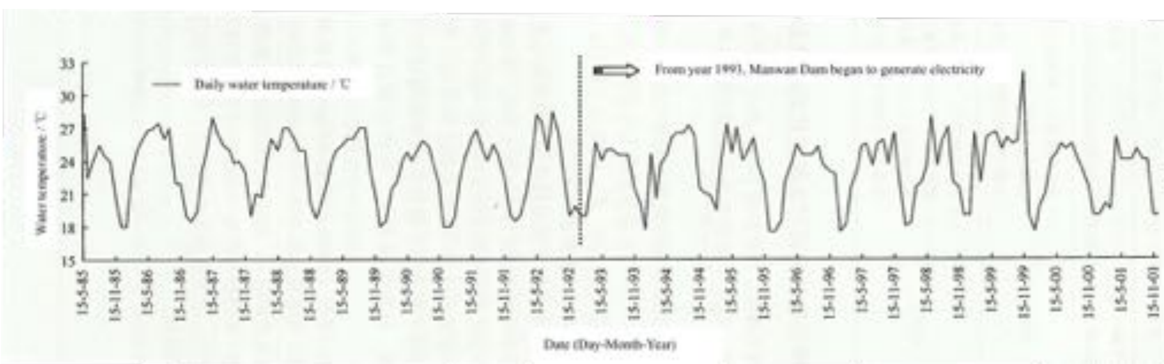
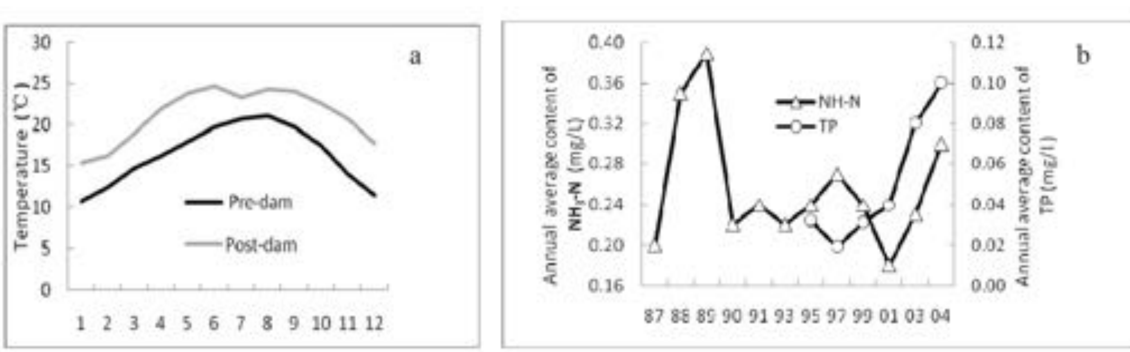


Figure 10 (a) Surface water temperature of Manwan transect in pre- and post-dam period;
(b) Annual average content of NH3-N and TP in Manwan area. [25]



21 Xui B S, Zhai H J. 2008. Quality evaluation of habitats disturbed by the Manwan Hydropower Dam [J]. Acta Scientiae Circumstantiae, 28(2): 227-234.

22. See No. 16
23. See No. 16
24. Baran E., 2006. Fish Migration Triggers in the Lower Mekong Basin and Other Tropical Freshwater Systems. MRC Technical Paper No. 14, Mekong River Commission, Vientiane. .
25. See No. 14

The ammonia nitrogen content in the pre-dam period was lower than in the post-construction period and increased sharply eight years after Manwan Dam was completed, due to the cumulative impacts of inundated plant decomposition, release from soil and sewage discharge, and decreased self-flushing and purification capacity in the reservoir. The total phosphorous content showed a similar trend (Figure 10).[26] Mining operations have developed in parallel with hydropower development on the Lancang, which has negatively impacted the water quality of the Lancang resulting in serious heavy metal pollution. These pollutants can travel downstream with the water flow, but there was no evidence that the water quality had deteriorated downstream.

3. Fishery

The Lancang dams have led to negative impacts on Lancang-Mekong fish species, such as blocking migration routes, fragmenting habitats, and changes in all aspects of the aquatic ecosystem including: the flow, depth dissolved oxygen levels, light, temperature and available food sources. Flow and temperature are both important triggers for fish migration. In the wet season river levels naturally increase, which triggers upstream migration.[27] The closure of dams will change the wet season flow by smoothing out the flow fluctuation and diminishing sharp spikes. The water temperature of dam discharge is lower than that of the pre-dam flows. Fish with a longer reproductive cycle, low adaptability and low breeding ability will be greatly impacted by the environmental changes and may even become locally extinct if they cannot adapt. [28]

3.1 Impacts on Migratory Fish Species

There are sixty-one known fish species that are found in Upper Mekong as well as the reaches of Lower Mekong Basin, however extent of fish migration from the Lower Mekong to the Upper Mekong is unknown. *Pangasius*, however, have been found to forage and spawn in the Buyuan River [29] and other fish species may also migrate between the Lower and Upper Mekong, e.g. *Tor sinensis, Wallago attu, Hemibagrus wychioides* [30]. One study found that four migratory fishes migrate over a long distance to spawn from the Mekong River to the Buyuan River in Xishuang Banna, China. However, traces of these four species have not been found above the Jinghong reach on the mainstream of the Lancang.[31] Of the eight cascade dams, Mengsong Dam attracted the most concern regarding the impact on fisheries, as it was likely to block the passage of migratory fish from the Lower Mekong to the Buyuan River (Figure 11). [32] The current status of Mengsong is that it has been officially cancelled.

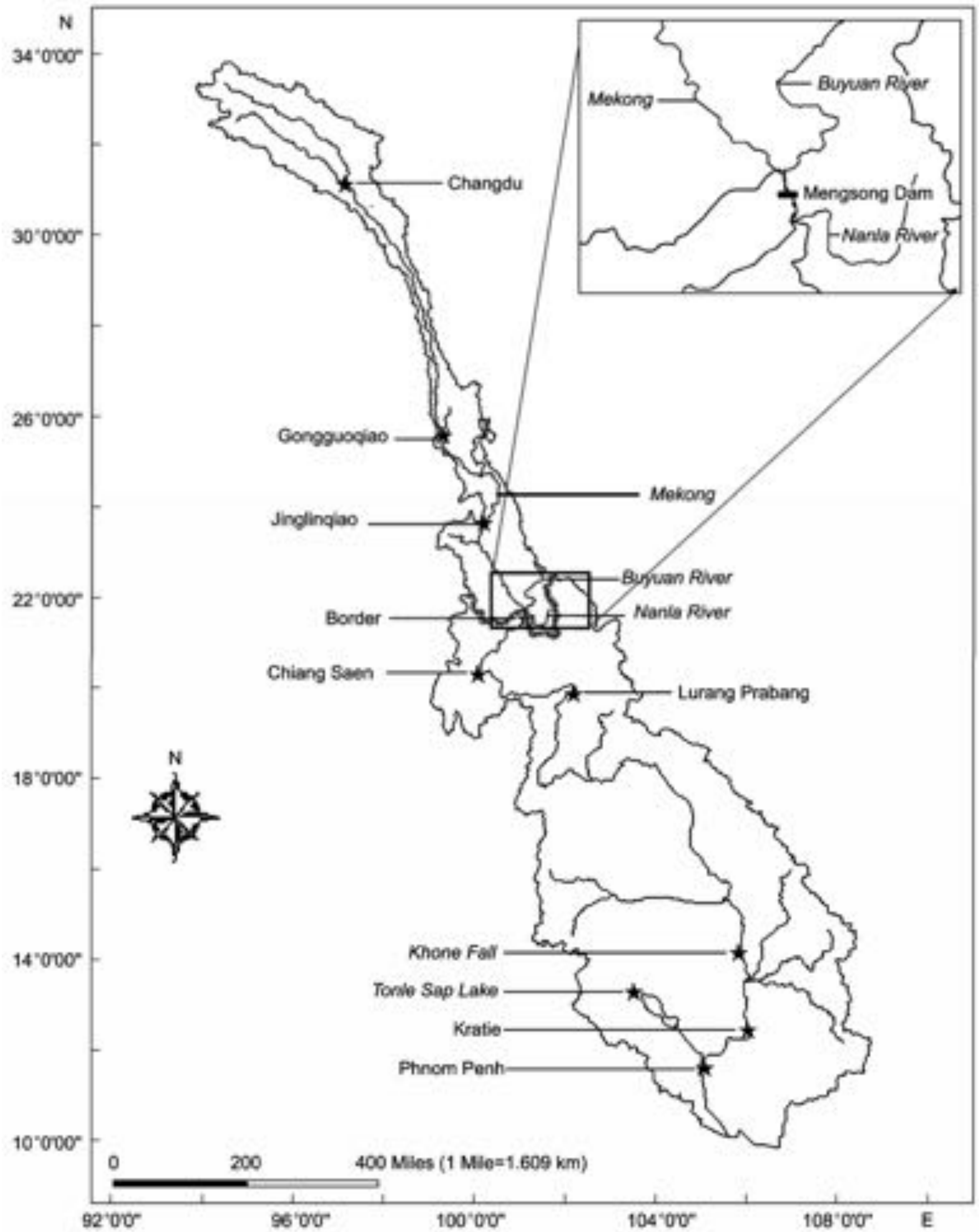
3.2 Impacts on Local Fish Species

Recent fish surveys[33, 34, 35, 36, 37] have observed a reduction in numbers of some fish species and great changes of fish species composition.

Liu et al., (2011) [38] conducted fish surveys in 2009 and 2010 and found that the number of fish species reduced from 139 to 80, compared to historic data collected along the Lancang River in Yunnan. The biggest changes occurred in the middle and lower Lancang River. Fish species from Siluridae, Sisoridae, Perciformes, Barbinae, Labeoninae, and Schizothoracinae have greatly decreased. Dam construction has caused the loss of habitats for demersal fishes which are more adapted to fast flowing conditions, such as Labeoninae and Cobitidae, and the fish species THAT live in the middle and bottom layers of flowing water, such as Siluridae, Sisoridae and Barbinae, because the dams cause the loss of living habitat, reproduction areas and food. Zheng et al., (2013) [39] was only able to capture 71 of 165 fish species historically recorded as middle and lower Lancang River types of fishes since 2008. The number of big fishes such as Tor Gray, Bagarius, and Bangana in the mainstream has largely decreased, while small and medium sized fishes have become dominant species.

26. See No. 14
27. See No. 24
28. Kang B., et al. 2009. Are the Fish of the Upper and Lower Mekong Interconnected? Chinese Journal of Oceanology and Limnology 27(2): 400-407
29. Yang, J., X. Chen and Y. Chen, 2007. On the population statusand migration of pangasiid catfishes in Lancangjiang River Basin, China. Zoological Research 1: 63-67.
30. Kang B., et al. (2006) Impacts and conservation on migratory fishes in the Lower Mekong under the developof cascade dams.
31. Zhou Shichun. Lancang River Hydropower Development, Environmental Protection, and Economic Contribution. Chiang Rai, Thailand. Oct. 16, 2009.
32. See No. 28
33. Liu M, et al. 2011. Fish Species Composition and Distribution in Lancang River in Yunnan. Journal of Fishery Sciences of China, 18(1): 156-170.
34. Zheng L P, et al. 2013. Status and Conservation of Fishes in the Middle and Lower Lancangjiang River. Zoological Research 34(6): 680-686.
35. He S P, et al. 1999. The Preliminary Investigation of Fish Biodiversity in Middle and Upper Reach of Lancangjiang River. Yunnan Geographic Environment Research 11(1): 26-29.
36. Li X Y, et al. 2010 Impacts of Manwan Dam Construction on Aquatic Habitat and Community in Middle Rearch of Lancang River. Procedia Environmental Sciences 2: 706-712.
37. Kang B, et al. 2009. Fish and Fisheries in the Upper Mekong: Current Assessment of the Fish Community, Threats and Conservation. 19: 465-480.
38. See No. 33
39. See No. 34

Figure 11 Locations of Mengsong Dam and Buyuan River [40]



40. See No. 28

The dams not only change the number of fish species, but also change their composition. Due to the development of aquaculture in the Manwan Dam, 15 new native species and 12 kinds of alien fishes were found after the dam was built. The introduction of alien species (e.g. *Neosalanx taihuensis, Carassius auratus auratus*) changed the former community structure and led to the disappearance of some local fish species. [41] The introduced fish species, such as *Oreochromis Mossambica,* which is commonly grown for commercial aquaculture, has become the dominant species[42].

Another reason for fish composition change in the Lancang River is the change of algae composition in the reservoir areas. The change in flow regime, combined with the change of surface water temperature and water quality after the construction of Manwan resulted in higher species numbers of algae and zooplankton in the Manwan area, which had increased by 192 and 101, respectively, as reported by Li et al., (2010). [43]

4. Sedimentation

Several reports concluded that half of the sedimentation in Lower Mekong came from the Lancang basin. Several reports[44, 45, 46, 47, 48] estimated the annual total sedimentation in Mekong basin to be 1.5-1.7 trillion tons, about 50% of which comes from the Lancang basin.

Plinston and He (2000)[49] estimated the annual sedimentation trapped by Manwan Dam to be 28.5-28.9×10^6t, not including sedimentation caused by landslides or erosion. The study concluded that 21.5% to 22.8% of the total storage capacity of the Manwan reservoir has been filled with sediment. It was reported that in the first three years of the dam operation, the bottom elevation of the reservoir increased by 30 meters due to sedimentation deposit. [50] The monitoring data from Jiuzhou and Jiajiu stations shows that the Manwan Dam trapped about 60% of suspended sediment in the water flow (Table 3 and Figure 12) [51]. The sedimentation capture rates of Gongguoqiao, Dachaoshan and Jinghong are about 30-40%, 60% and 60%, respectively. [52]

Table 3 Estimation of Sediment trapped by the Manwan Dam (10^6 t)[53]

Year	Measured sediment load (Jiuzhou)	Measured sediment load (Jiajiu)	Modelled sediment load (Jiajiu)	Sediment trapped by the Manwan Dam
2003	32.85	13.2	48.95	35.75
2002	26.43	21.77	39.39	17.62
2001	25.91	15.88	38.60	22.77
2000	48.89	24.96	72.86	47.90
1999	24.86	12.89	37.04	24.15
1998	44.57	26.45	66.42	39.97
1997	13.97	5.41	20.8	15.39
1996	22.85	8.61	34.06	25.44
1995	23.26	18.16	34.66	16.50
1994	9.45	1.72	14.09	12.37
1993	44.8	37.33	66.76	29.43
Average	28.8	16.94	43.06	26.12

Kummu (2007)[54] estimated the theoretical trapping efficiency figures for each dam (Figure 13), and his findings are very similar to Chinese researchers' results. The whole cascade of dams will theoretically trap 94% of the suspended sediment load coming from China, Kummu estimated. By analyzing the MRC water quality monitoring database and the MRC hydrological database, he found that the sedimentation at Chiang Saen decreased from an average of 71 million tons/yr in 1962-1992 to 31 million tons/yr (1993-2002). Similarly, the sediment load at Pakse decreased from 133 million tons to 106 million tons. Lu (2006)[55] found that the sediment load at Chiang Sean decreased from 74 million

41. See No. 33
42. See No. 37
43. See No. 36
44. Milliman J D, Meade R H. 1983.World-wide delivery of river sediment to the oceans. J Geol, 91:1-21
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tons before 1993 to 34.5 million tons per year in 1993-2000, and that the sedimentation impacts from Manwan extends toVientiane.

However cross-verified estimates of the impact on sedimentation are difficult not only because China and downstream countries adopt different measurement methodologies, but also because some data is missing. For example, Fu et al (2008)[56] used a different analysis methodology and suggested that the impact of sedimentation change by the Manwan Dam is very limited even at Yunjinghong station in Yunnan.

Figure 12 Measured sediment loads in 1965-2003 at Jiuzhou and Gaijiu stations on Lancang River[54]

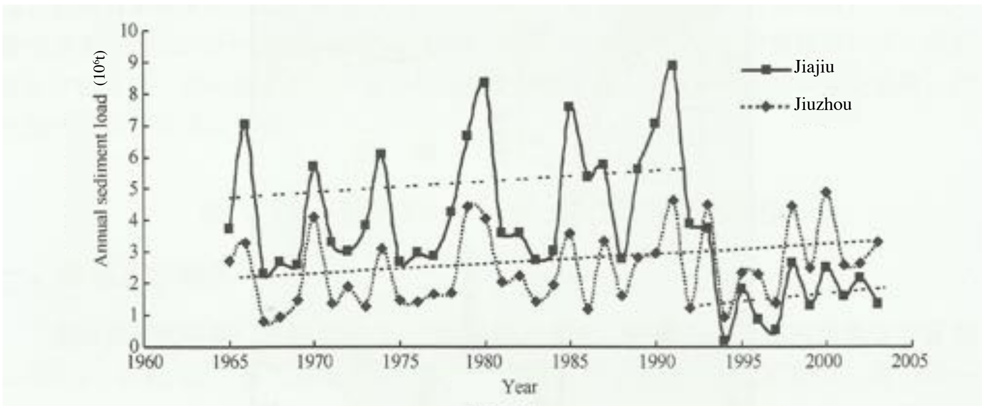
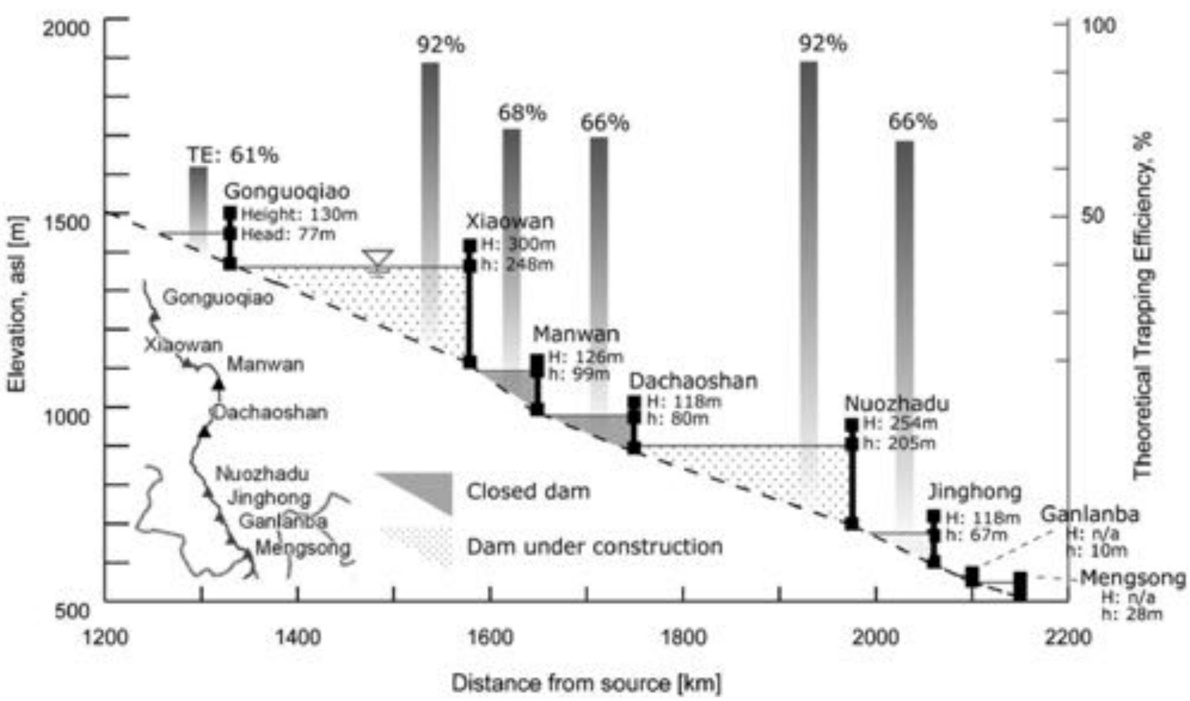


Figure 13 Profile of the Lancang Cascade with average theoretical trapping efficiency of each reservoir



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MORE INFORMATION

Lancang River Dams Factsheet: http://www.internationalrivers.org/resources/lancang-river-dams-threatening-the-flow-of-the-lower-mekong-2674
Background on the Lancang/Mekong River: http://www.internationalrivers.org/campaigns/mekong-lancang-river
Interactive map of major dams on the Lancang River: http://goo.gl/maps/epwHc
Spreadsheet of major dams in China: http://www.internationalrivers.org/node/7743
Photos of dams on the Lancang: http://www.flickr.com/photos/internationalrivers/sets/72157621766522052/

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