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How cascade reservoirs impact on spawning activity of four major Chinese carps in the upper Yangtze River?

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Objectives

As the successive impoundment of Wudongde (WDD) and Baihetan (BHT) reservoirs in the upper Yangtze River (UYR), these two giant reservoirs have formed the large-scale cascade reservoirs together with the other two giant reservoirs, i.e. Xiluodu (XLD) and Xiangjiaba (XJB) reservoirs, which have been operated for several years. These reservoirs will further affect the flow regime of the UYR. Therefore, the main objectives of this research mainly includes the following two aspects: (a) by coupling the habitat suitability curves and the 1-D mathematical model, a HSI model for the four major Chinese carps (FMCC), i.e. bighead carp (*Aristichys nobilis*), grass carp (*Ctenopharyngodon idellus*), black carp (*Mylopharyngodon piceus*), and silver carp (*Hypophthalmichthys molitrix*), was established; (b) the influence of the construction and operation of the cascade reservoirs and corresponding changes of regional hydrology on the FMCC spawning activity were examined and discussed.

Methods

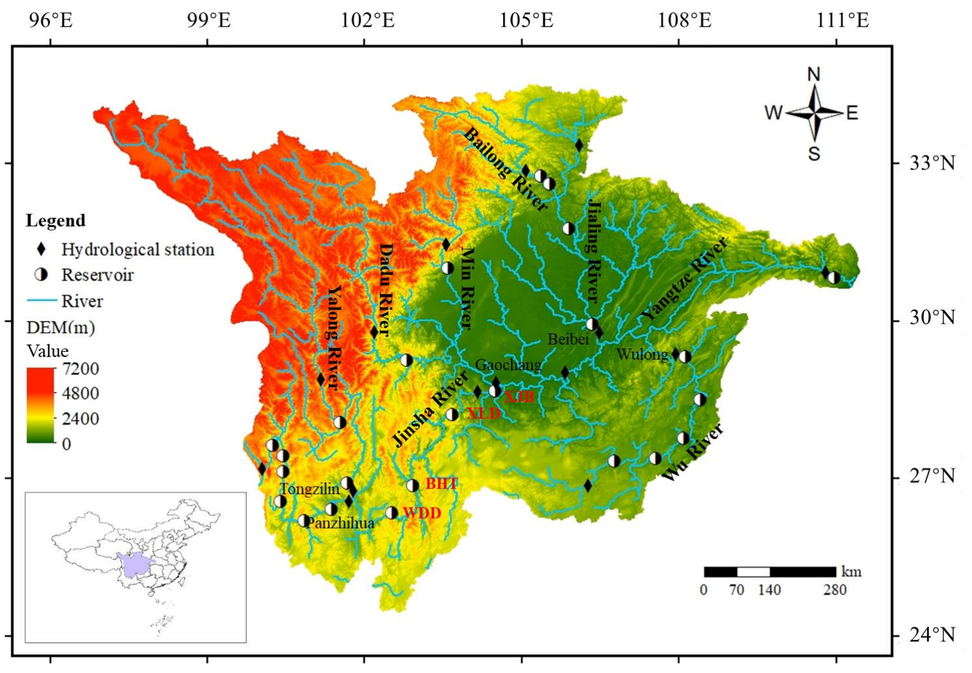

Fig. 1. Location and topography of the study area.

Hydrodynamic modeling

The unsteady water flow dynamics in a channel can be described by the Saint-Venant equations:

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q \tag{1}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+gA\frac{\partial Z}{\partial x}+g\frac{Q|Q|}{C^2AR}=qu \tag{2}$$

Habitat suitability curves (HSCs)

According to literature research, the HSI of the FMCC is mainly characterized by the flow velocity (HSIV), range of water level rise (HSIRD), and water depth (HSID) (see Fig. 2).

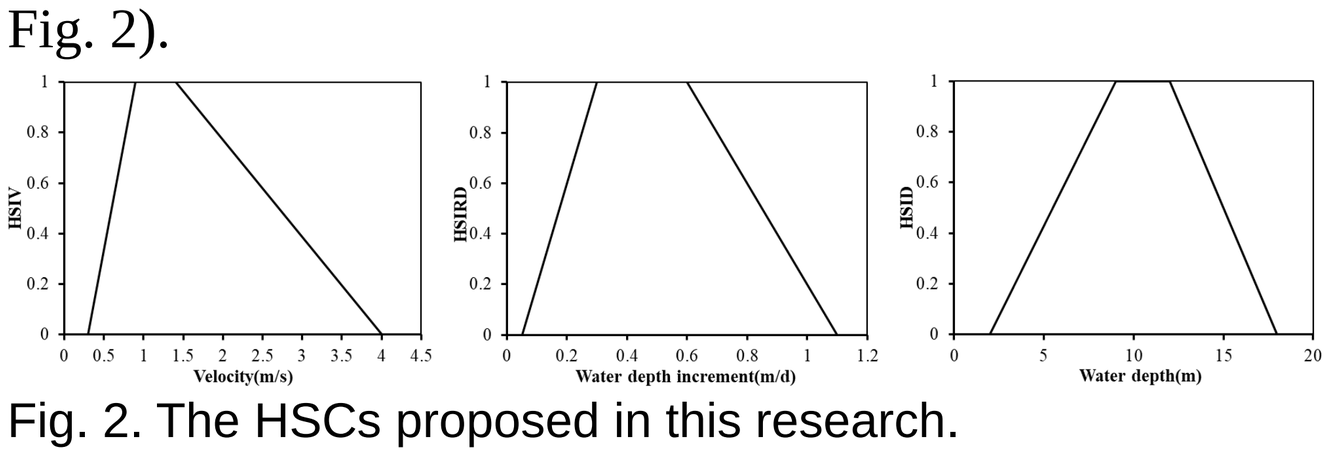

Fig. 2. The HSCs proposed in this research.

Results

After the operation of WDD and BHT reservoirs, the flood process tends to be uniform, and the recession process is not obvious between the end of April and early May, which weakens or disappears the first spawning signal of FMCC. Except for the 4 days delay of the first spawning time in 2016, the delay of the first spawning time in other years was more than 12 days, and the longest was 30 days in 2012 (see Fig. 3).

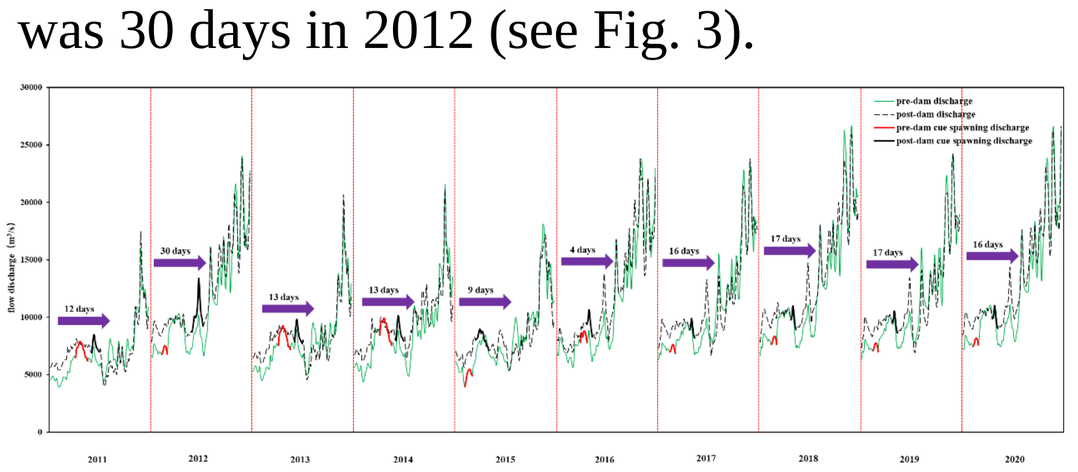

Fig. 3. Comparison the date of flood processes occurrence that may stimulate the first spawning each year of FMCC between before and after cascade reservoirs operation.

The results of this study indicate that during the spawning season of the FMCC from late April to July, the various components of the flow pulses, including the rate, duration, and magnitude of the increases in flow, were significantly reduced after the reservoir impoundment (see Fig. 4). Modified flow environment in spawning season has a negative effect on FMCC spawning.

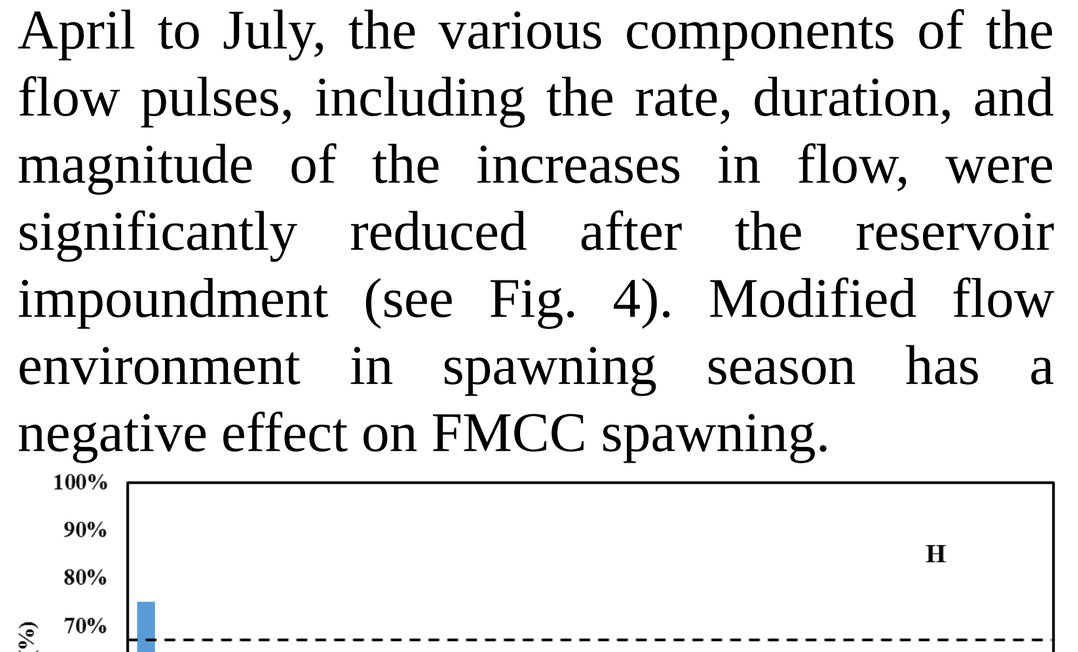

Fig. 4. Ranked median absolute degrees and percentile value of indicators of hydrologic alteration before and after cascade reservoirs operation.

Conclusions

The operation of cascade reservoirs has significantly changed the flow regime in the UYR. The first spawning time of the FMCC would be delayed for more than 12 days. The changed flow regime will have a negative impact on the spawning volume of the FMCC.