The Effect on the Flow Conditions of Chinese Sturgeons’ Spawning Sites in the Process of Peak Regulation between the Three Gorges Dam and Gezhou Dam

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Abstract

Chinese sturgeon (Acipenser sinensis Gray) is a kind of key protected fish in ChangJiang river. Recently the Three Gorges dam has run, the peak regulation process between the two dams has serious effect on the formed spawning sites. Based on the previous research results of suitable flow conditions about the spawning sites, this article builds a 2-D shallow water numerical model, calculates the flow conditions of the spawning sites in the process of peak regulation. The results show that the water depth and velocity are various and affect the spawning sites in one 24-hours process of peak regulation, as a whole, when the discharge is below 9000 m3/s and 7500 m3/s respectively, the two spawning sites will be affected seriously.

Introduction

Chinese sturgeon (Acipenser sinensis Gray) is a kind of anadromous and key protected fish in ChangJiang river, each year, which will come back from sea to the upstream of ChangJiang river for spawning. Related researches show that [1-3], there are significant relationships among velocity, water depth, topography with the location of Chinese sturgeons’ spawning site.

After the GeZhou dam was built, the migration route of Chinese sturgeon had been cut off, the numbers of Chinese sturgeons are decreasing, and even so, because of natural stress effect, two new spawning sites were formed in the downstream of GeZhou dam with suitable flow conditions [1], which are shown in figure 1 with white closed curves and here called up spawning site and down spawning site.
But recently the Three Gorges dam has run, the peak regulation process between the two dams has serious effect on the existed spawning sites. So it is important to grasp the varying of spawning site in the regulation process.

By field measuring, we can know the flow condition more truly, but which will cost much more, and also can not get the flow field of the whole river easily. Therefore, the numerical model was adopted to study the effect on the spawning site.

Method

A. Hydrodynamic model

The two-dimensional shallow water equations are used that are given below.

\[
\begin{align*}
\frac{\partial H}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} &= 0 \\
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} &= -\rho \frac{\partial p}{\partial x} + f v + v \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) + \frac{1}{\rho H} \tau_x, \\
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} &= -\rho \frac{\partial p}{\partial y} - f u + v \left( \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) + \frac{1}{\rho H} \tau_y
\end{align*}
\]

Where, \( H \) is water level (m); \( u, v \) are velocity in \( x \) and \( y \) direction (m/s); \( v \) is horizontal eddy viscosity coefficient (m\(^2\)/s); \( f \) is Coriolis parameter; and \( \tau_x, \tau_y \) is bottom shear stress (N/m).

The implicit scheme was used to stabilize the numerical solution, and the ADI method was applied. Due to the varying discharge process, the moving boundary method was adopted.

B. Boundary condition

1) Upstream boundary condition
As sketched in figure 1, the power plants of Dajiang and Erjiang are the upstream boundaries. The 24-hours peak regulation process was used as the upstream boundary condition. The regulation rule between Three Gorges and GeZhou dam is shown in figure 2. Take the discharge process of GeZhou dam as the upstream boundary condition.

![Diagram](image)

**Figure 2.** the 24-hours peak regulation process of GeZhou and Three Gorges dam

2) **Downstream boundary condition**

The water level-discharge rating curve was used as the downstream boundary condition.

**C. Model calibration**

Under the incoming flow condition of 10000 m$^3$/s and 15000 m$^3$/s, comparing the observed and simulated water level in the seven observed points from upstream to downstream, the maximum relative error is 0.79%, and in most of the observed points, the relative error is about 0.3%, the flow field is reasonable, the specific calibration data can be found in [4]. So the model can simulate this river well, and can provide reasonable flow characteristic of spawning site.

**Results**

As shown in figure 1, we set two cross-section (I and II) located at the up and down spawning sites respectively, and accordingly settle six analysis points (I R, I L, II R, II M and II L). According to related research[2], the selected suitable velocity is between 1.1 and 1.7 m/s, and water depth is between 6 and 15 m. Analyzing the velocity and water depth value of these analysis points respectively, comparing the value with suitable range, and then we can conclude the influence degree of existed spawning sites by the peak regulation process.

**D. Cross-section I**

I R locates at the existed up spawning site. As shown in figure 3, in the whole peak regulation process, the water depth can meet the spawning requirement, except about form 23:00 to 7:00 when the water depth is a little small and the discharge is the minimum of the process; but only when the discharge is more than 9000 m$^3$/s, the velocity can meet the spawning requirement. So when the discharge is below 9000 m$^3$/s in the peak regulation process, there are unfavorable influences on existed up spawning site.
I L locates at the left of existed up spawning site. As shown in figure 4, although when the discharge is more than 7500 m$^3$/s, the velocity and water depth all can meet the spawning requirement, but the downstream of this point is a deep pool, the elevation will decrease sharply, which is not in accordance with the topography requirement for spawning. So this area will not form a suitable spawning site.

E. Cross-section II

II R locates at the right of existed down spawning site area. As shown in figure 5, the water depth of II R can meet the spawning requirement in the whole peak regulation process; and the velocity is a little small in the minimum discharge period.
Figure 5. the varying process suitable period of water depth and velocity in analyzing point II R

II M locates at the middle of rive section of existed down spawning site. As shown in figure 6, only when the discharge reaches to the maximum value, the water depth and velocity are a little bigger than the requirements.

Figure 6. the varying process suitable period of water depth and velocity in analyzing point II M

II L locates at the existed down spawning site. As shown in figure 7, in the whole peak regulation process, the water depth can meet the spawning requirement, except about form 23:00 to 7:00 with the minimum discharge when the water depth is a little small; but only when the discharge is more than 7500 m³/s, the velocity can meet the spawning requirement. So when the discharge is below 7500 m³/s in the peak regulation process, there are unfavorable influences on existed down spawning site.
Conclusions

Under the 24-hours peak regulation process, when the discharge is below 9000 m³/s, there are unfavorable influences on existed up spawning site.

When the discharge is more than 7500 m³/s, most area of down spawning site can meet the spawning requirement, because of the topography of left bank is better than right bank for spawning, so the Chinese sturgeons will spawn there firstly. When the discharge is below 7500 m³/s, there are unfavorable influences on left bank of existed down spawning site, because of the natural stress effect, the spawning site will move to the right bank.

Actually, the spawning site also be affected by temperature, sediment, water quality and other factors, in the future study, we can consider these factors for integrated analysis; otherwise, the Chinese sturgeon is a kind of anadromous fish, the 2-D shallow water model can not reflect the vertical distribution of flow condition well, so the 3-D model should be adopted in the future.

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