

The Effects of Topographic Change on the Trajectory of *Patinopecten Yessoensis* Larvae

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Abstract. The spatial and temporal distribution of *patinopecten yessoensis* larvae has high uncertainty, leading to the difficulty of harvest natural seedlings. Based on the survey data of and the numerical results by DHI MIKE, the effects of topographic change on the trajectory of the larvae was discussed. Hydrodynamic field model was built to simulate the flow fields of North Yellow Sea and tidal harmonic constants were used to verify the model. The particle tracking model was used to simulate the passive drift and diffusion of *patinopecten yessoensis* larvae by the flow field while the bay topography was changed. The results shows, with the topography change of bay, the *patinopecten yessoensis* larvae drifting trajectory could be changed.

Introduction

Patinopecten yessoensis belongs to cold water bivalve shellfish and is native to Hokkaido, Russian Far-East and North Korea which was introduced to China in the 1980s. The large-scale farming of *patinopecten yessoensis* has been carried out in the sea area near Zhangzi Island in the north of Yellow Sea. Compared with the disadvantages of high cost and negative resistance of artificial seedling, the wild seedlings have the advantages of strong constitution, strong resistance and no pollution. Furthermore the growth rate and survival rate of wild seedlings are higher than that of artificial seedlings^[1-2]. However it takes *patinopecten yessoensis* planktonic larvae more than 20 days from spawning to settlement. Due to the natural environmental factors such as current, planktonic larvae are transported to a distance more than hundreds of kilometers, leading a high instability of their spatial temporal distribution and great difficulties in natural spat collection.

The bio-physical coupling model is considered as an effective means to simulate the drifting trajectory of the larvae from the spawning sites to the seedling collection areas^[3-4]. This paper discusses the effect of the topography change on the larvae drifting trajectory, attempts to make *patinopecten yessoensis* larvae be reserved near the spawning site.

Hydrodynamic model

Governing equations

Two-dimensional governing equations were adopted in this calculation. Eq.(1) is the continuity equation, Eq.(2) and Eq.(3) are the momentum equations in x and y direction. Eq.(4) is the equation calculating the turbulent viscosity coefficient. In which equations, ζ is water level, d is the height of the seafloor, h is water depth, p and q is the single width flow in x and y direction. C is the Chézy coefficient, g is the acceleration of gravity; f is the friction coefficient; V , V_x , V_y represent wind speed and its components in x and y direction respectively. Ω is Coriolis force coefficient, P_a is the atmospheric pressure; ρ_w is the density of water; t is time; E is the viscosity coefficient of flow turbulence, u and v are the components of the velocity in the x and y direction.

$$\frac{\partial z}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = \frac{\partial d}{\partial t} \quad (1)$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x} \left(\frac{p^2}{h} \right) + \frac{\partial}{\partial y} \left(\frac{pq}{h} \right) + gh \frac{\partial z}{\partial x} + \frac{gp\sqrt{p^2 + q^2}}{C^2 h^2} - \frac{1}{r_w} \left[\frac{\partial}{\partial x} \left(Eh \frac{\partial p}{\partial x} \right) + \frac{\partial}{\partial y} \left(Eh \frac{\partial p}{\partial y} \right) \right] - \Omega q - fVV_x + \frac{h}{r_w} \frac{\partial}{\partial x} (P_a) = 0 \quad (2)$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial y} \left(\frac{p^2}{h} \right) + \frac{\partial}{\partial x} \left(\frac{pq}{h} \right) + gh \frac{\partial z}{\partial y} + \frac{gp\sqrt{p^2 + q^2}}{C^2 h^2} - \frac{1}{r_w} \left[\frac{\partial}{\partial y} \left(Eh \frac{\partial p}{\partial x} \right) + \frac{\partial}{\partial x} \left(Eh \frac{\partial p}{\partial y} \right) \right] - \Omega p - fVV_y + \frac{h}{r_w} \frac{\partial}{\partial y} (P_a) = 0 \quad (3)$$

$$E = C_s^2 (\Delta x \Delta y)^2 \sqrt{\left(\frac{\partial u}{\partial x} \right)^2 + \frac{1}{2} \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right) + \frac{\partial v}{\partial y}} \quad (4)$$

Spatial discretization

HD-FM and particle tracking model in DHI MIKE were adopted in the simulation and non-structural grid and finite volume method were used. When the control equation is discrete, the variable *u* and *v* are located at the center of the unit, and the other variables are defined at nodes of the unit.

Calculation condition

The topographic map of the calculating area is shown in Fig.1, which was near Zhangzi Island that was the natural growth area of the *patinopecten yessoensis* in the North Yellow Sea. The land and water depth information are adopted with wgs-84 geodetic coordinates. Four main constituent harmonic constants (*M₂, S₂, K₁, O₁*) of the region were selected as initial conditions to generate the water level time series. The closed boundary condition was zero for water quality point and initial velocity and the tidal level were zero. 18575 nodes and 35076 grids were adopted in this calculation.

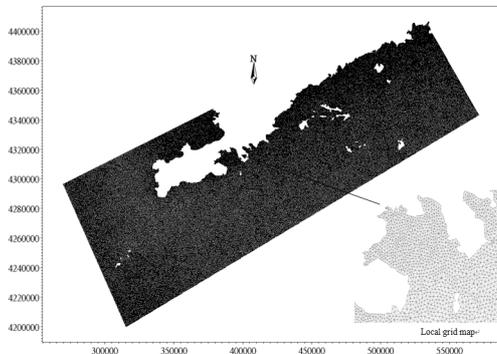


Fig.1 Topographic map of the calculating area

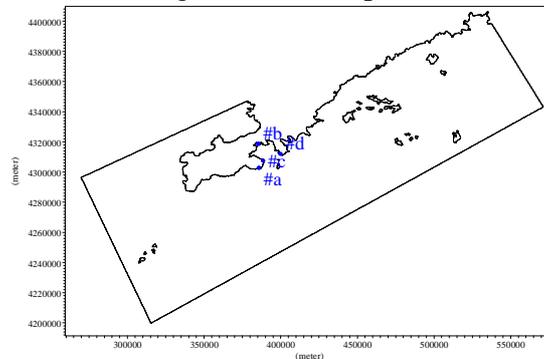


Fig. 2 Tide station location

Tidal current verification

Due to lack of measured data in the simultaneous segment of the calculation region, this paper selects non-simultaneous verification on tidal current verification. The current survey stations selected in the model area are shown in Fig.2. Fig.3 is the comparison between the measured tide level and the calculated ones, which shows the consistency of the calculated results and the measured ones.

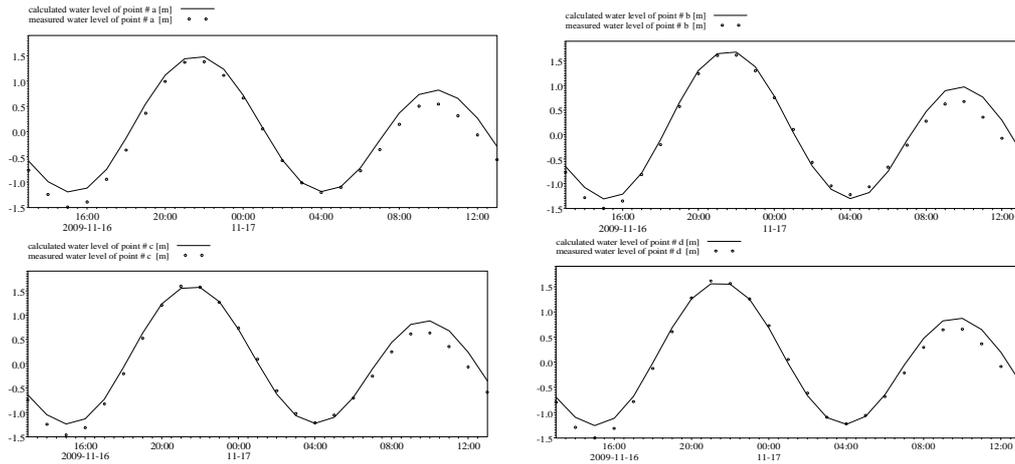


Fig.3 Comparison of calculation and observation

Tidal current analysis

The tidal current field calculated was shown below. Fig.4 and Fig.5 show the flooding tide and ebb tide at spring tide and neap tide. For the flow direction, when it is spring tide, the tidal current direction is SW to NE at the flood tide and is NE to SW at the ebb tide. The tide trends towards the shoreline at flooding tide but it has a tendency to turn outer sea at ebb tide. For the flow velocity, the one of the outer sea area is greater than that of the near shore region. And the tide flow velocity at flooding tide is greater than that at ebb tide in calculation area. It can be seen that the simulated flow field characteristics is in accordance with the real flow field. Therefore, the tidal current hydrodynamic model can provide a powerful and reasonable flow field foundation for the construction of the following model.

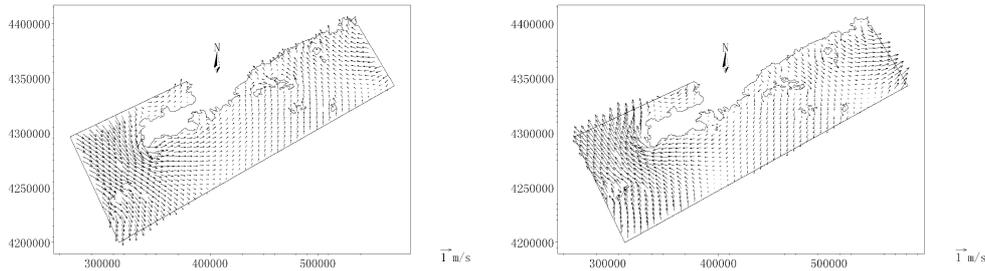


Fig.4 Flooding tide and ebb tide flow field at spring tide

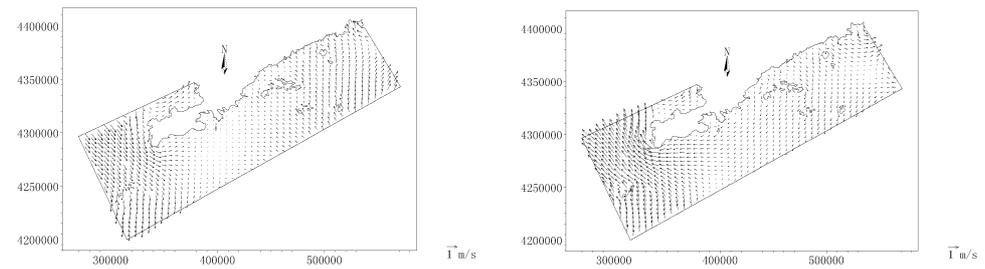


Fig.5 Flooding tide and ebb tide flow field at neap tide

Particle tracking model

Governing equations

The transport and turbulence diffusion process of particles is described by Langevin equation in Eq.(5)^[5]. In which, a represents transport coefficient; b is the diffusion coefficient; r is random number. When calculating the trajectory of a discrete value at a given time, the initial value is set to $Y_0=X_0$, and the value of Y is solved by Eq.(6). In which, $n=1,2,3... W=W_t-W_s$. It's Gaussian increment in a continuous period based on wiener progress^[6].

$$dX_t = a(t, X_t)dt + b(t, X_t)x_t dt \tag{5}$$

$$Y_{n+1} = Y_n + a(t, X_t)Y_n\Delta_n + b(t, X_t)Y_n\Delta W_n \quad (6)$$

Numerical methods

MIKE 21 FM Particle Tracking module uses Lagrange discrete method, which was to simulate the material quality of average assigned to a large number of particles. The advantage of this method is the value dissipation is very small. In terms of simplifying the model, the interaction between different particles is not considered. After particles released, the velocity of movement in the water is consistent with the velocity of the surrounding water, and the particle is reduced to the fluid particle^[7].

Numerical results

The simulation time is from April 1, 2017, to May 30, 2017. Topography was changed in Erbiantan Bay of Zhangzi Island by setting a embankment at the bay mouth as shown in Fig.7. The particle was released from Erbiantan Bay. Fig.6 shows the drifting trajectory of *patinopecten yessoensis* larvae when the topography is not changed and Fig.7 shows the trajectory when the topography at the bay mouth was changed. When the topography is not changed, the particle drifting trajectory is from southeast of the bay to the bay outside. However, when the topography is changed, the particle drifting trajectory is from northwest of the bay to the bay outside.

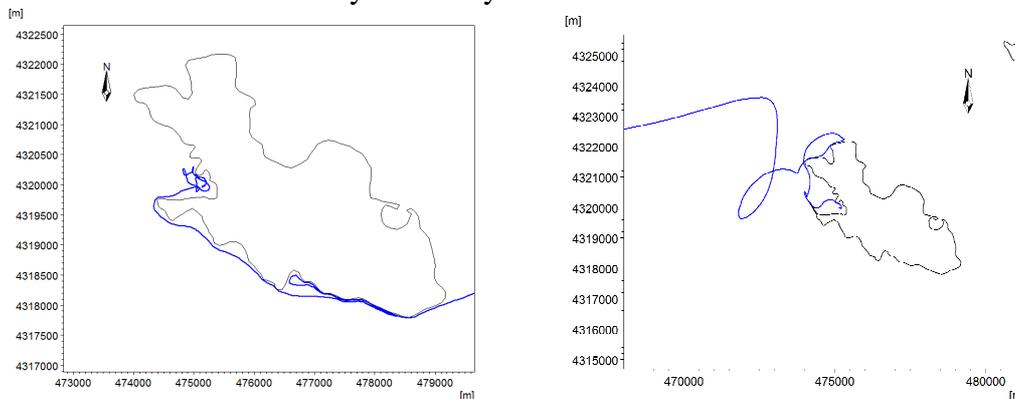


Fig.6 Bay topography no change larvae trajectory Fig.7 Bay topography change larvae trajectory

Conclusions

The *patinopecten yessoensis* larvae drifting trajectory can be changed under the condition of bay topography change. Furthermore the *patinopecten yessoensis* larvae can be retained in the bay through suitable bay topography change methods.

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