4. Research report (Follow the guideline on the next page)

Numerical studies on Japanese anchovy larval growth and transport in the Yellow Sea

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1 Purposes

The Yellow Sea (YS, including the Bohai Sea (BS) in this project) is a semi-enclosed marginal sea located in the northwestern Pacific Ocean. Japanese anchovy is one of the key small pelagic fish species (SPF) in the YS which plays a significant role in the whole marine ecosystem (Zhao et al., 2003). During the early life stages, the fish eggs and larvae are passively transported by ocean currents, while experiencing aggregation and dispersion (Xing et al., 2020). The fish eggs and larvae are more vulnerable compared with adults (Xing et al., 2021). Many studies have suggested that eggs and larvae tend to be trapped in particular zones, called "Larval Retention Areas (LRA)" in the ocean (Stephenson et al., 2015; Hidalgo et al., 2019).

In this study, the aggregation and dispersion of eggs or larvae will be simulated by a Lagrangian particle-tracking model coupled with a hydrodynamic model. Based on a simple algorithm developed by Xing et al (2020), larval retention level of Japanese anchovy in the YS will be quantified, as well as the retention area.

2 Methods

1) Fish species

Japanese anchovy is one of the key small pelagic fish species (SPF) in the YS and it's the main prey for 30–40 predatory fish species. Its spawning season can last from April to October with a peak in June.

2) Hydrodynamic model

In this study, the Princeton Ocean Model (POM, Blumberg and Mellor, 1987) was adopted to provide hydrodynamic fields for the YS. Its horizontal resolution is 1/18°, which is about 5 km, with 21 sigma layers in the vertical direction, and the time step is set as 1 hour. The calculation area of the POM model is the entire YS (31.0°-41.0°N, 117.0°-127.0°E) and the hourly current data from 2018 were obtained by the model.

3) Biological setting

The particles were assumed to be uniformly released in the surface water where the water depth is less than 40 m. And the particles were only transported in the surface. The number of released eggs changed over time because of the spawning habit of Japanese anchovy. The suitable temperature range of particles during transport was set at 13-28°C. When the temperature exceeds this, particles die. The particles were released once on 1st, 11th and 21st of April to August every year at 00:00 hours (because spawning takes place around midnight), 5*5=25 particles per grid, each particle representing σ anchovy larvae. σ varied with time, with the highest value at the peak spawning period (normal distribution). All the particles were passively tracked for 30 days.

4) LRA algorithm

A universal standardized Larvae Retention Index (SLRI) to identify the LRA by an appropriate threshold:

$$SLRI\,(c) = \frac{f\,(c) - \min(f)}{\max(f) - \min(f)}$$

$$f\,(c) = \frac{\int_{t_1}^{t_2+T} Ir\,(c,\,t)dt}{t_2 + T - t_1}$$

$$Ir(c,\,t) = \frac{\sum_{i=1}^{N\,(c,t)} n(i,\,c,\,t) - \sum_{i=1}^{N_0(c,t)} n(i,\,c,\,t)}{\sum_{c=1}^{Q} \sum_{i=1}^{N\,(c,t)} n(i,\,c,\,t)}$$

(Xing et al., 2020)

where SLRI(c) represents the Standardized Larval Retention Index of the c^{th} grid, $Ir(c,t)$ denotes the instantaneous retention rate of the c^{th} grid at time t, t_1 and t_2 are start and end time of spawning, T is the pelagic larval duration (PLD) and $n(I,c,t)$ is the number of the particles represented in the c^{th} grid at time t, $N(c,t)$ is the total number of particles in the c^{th} grid at time t and $N_0(c,t)$ is the number of particles released from the c^{th} grid and are staying in this grid at time t, Q is the total number of grid in the study area.

3 Results

The released particles were transported only in the surface layer of YS. As shown in Fig. 1, from April to August, the high surface velocity in the Kuroshio extension area on the southeast side of YS is very obvious. In addition, the northward coastal current in the southern side of the Shandong Peninsula and the Subei shoal is also strong, especially in July. This has a great effect on the direction of the particle transport. However, the current field of the BS is relatively weak, and the particles are not easy to be transported out, which is conducive to the retention of particles. The successful release of particles depends on the depth and the surface seawater temperature. Through experiments, we know that particles can be released successfully in most areas of the BS and along the coasts of the YS (Fig. 2).

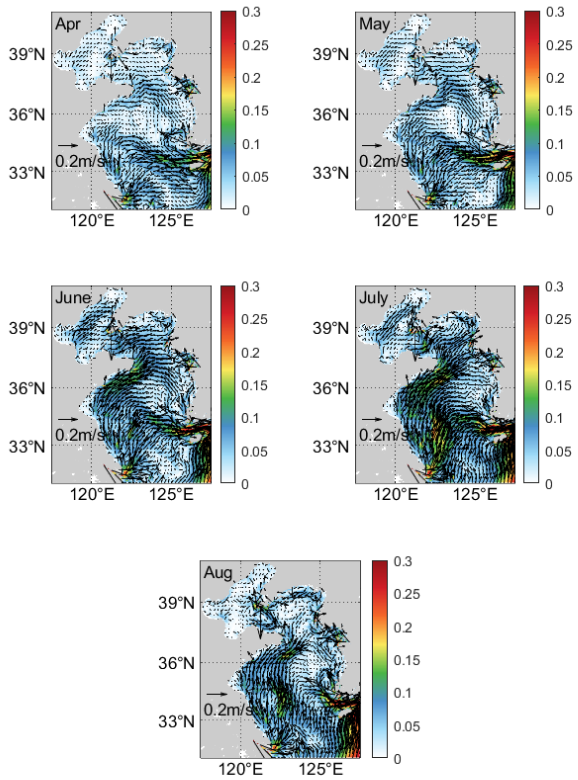

Fig. 1. Monthly mean surface current field from April to August in 2018.

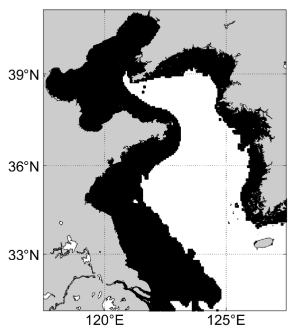

Fig. 2. Initial position of the particle released on June 21, 2018.

Based on the particle-tracking simulation results, we calculated the total SLRI (from Apr 1st to Sep 20th 2018) for Japanese anchovy in YS which was shown in Fig. 3. There is process yielded one LRAs in each of both BS and NYS, while three LRAs were identified in the western and eastern parts of the SYS. LRAs-I occupies greater part of BS. LRAs-II is mainly located along the coast southeast to Liaodong Peninsula. LRAs- III and LRAs-IV are located in the south of Shandong Peninsula and the northeast of Yangtze River Estuary respectively. LRAs-V is located in a small area off the western coast of the Korean Peninsula. The absence of LRA in central YS suggests that most eggs or larvae are mostly transported to shallow water during the early life stages of Japanese anchovies.

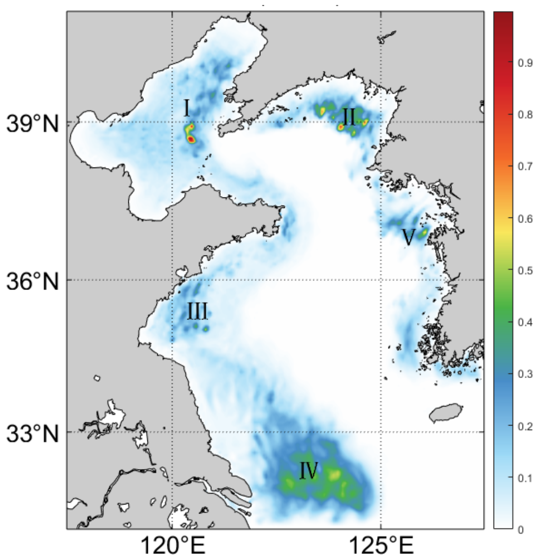

Fig. 3. The distribution of SLRI and LRAs of Japanese anchovy in YS in 2018.

4 Future challenges

1) The LRAs results obtained so far represent only average levels over the entire spawning period, and further analysis of LRAs can then be performed based on temporal variation of Ir.

2) The growth rate is derived from the water temperature ($y = -2.302 + 0.255 \times x - 0.006 \times x^2$, where y is the larval growth rate and x is water temperature, Takasuka et al., 2007). Along the tracking path of each particle, we will calculate the mean growth rate to identify the key spawning/nursing period and grounds for Japanese anchovy.

3) The interannual changes and influencing factors of LRAs and the key spawning

/nursing period and grounds will be analyzed during 2010 to 2020.

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