Analysis of the distribution characteristics and environmental impacts of green tide in the Yellow Sea

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1. Aim

Three main aims were carried out during the year: (1) A coupled physical-ecological model (LTRANS-GT) based on the Lagrangian transport model (LTRANS) was constructed to simulate the growth and extinction process of *Ulva prolifera* and obtain its drift trajectory and biomass (wet weight). (2) Analysis the Characteristics of drift paths and biomass changes of Yellow Sea *Ulva prolifera*. (3) Uptake of nitrogen and phosphorus salts by green tide outbreaks and impact of green tide

2. Data and method

The ecological dynamics model of the Yellow Sea green tide was divided into two main parts: the drift module and the ecological module (Fig. 1). The drift module adopted the Lagrangian particle tracking method based on the LTRANS model. It used the sea surface wind field and surface flow field data as the driver to calculate the drift trajectory of the green tide. Environmental factors such as sea surface temperature, light intensity, and nutrient salts were considered in the ecological module to establish ecological equations for the growth and mortality of *Ulva prolifera*. The ecological module was further coupled with the LTRANS model to develop a coupled ecodynamic model (LTRANS-GT) to calculate the green tide distribution and growth processes.

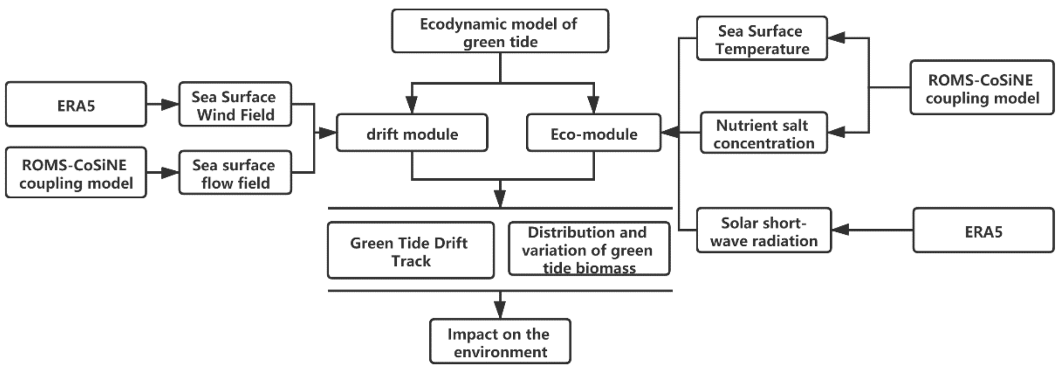

Fig. 1. Ecological dynamics model of green tide in Yellow Sea

The sea area simulated by the model was located at 118-128 °E, 32-38 °N, and the time range was from 2008 to 2017. The model output results every 24 h, which included the latitude and longitude of the *Ulva prolifera* particles, the weight of the *Ulva prolifera* particles, the environment (light, temperature, nutrient concentration) where the *Ulva prolifera* particles were located, etc.

3. Results

3.1 *Characteristics of drift paths and biomass changes of Yellow Sea Ulva prolifera*

The simulated path characteristics had interannual differences. We divided the drift paths of *Ulva prolifera* into three categories and named them northwestward drift, northeastward drift and northward drift according to the different initial drift direction. The northwestward drift, which included the three years of 2008, 2010 and 2011, was characterized by the main body of the green tide drifting northwestward toward the shore at the beginning of the outbreak and then drifting northeastward, parallel to the shoreline. The northeastward drift, which included the three years of 2009, 2012 and 2017, was the path where the main body of the green tide drifted eastward at the beginning of the outbreak and the drift direction was mainly northeast. The northward drift path, which included the four years from 2013 to 2016, was characterized by a northward drift of the main body of the green tide at the beginning of the outbreak, followed by a northeast drift parallel to the shoreline. In all years, the green tide affected the area from approximately 37 °N in the north, Rudong in Jiangsu Province in the south, Lianyungang in Jiangsu Province in the west, and 125 °E in the east.

We compared the weight of the model-simulated Ulva prolifera with the green tide coverage area from remote sensing images, and we could see that the seasonal change characteristics of biomass in most years was in good agreement with the change trend of the coverage area obtained from remote sensing images. Additionally, from the simulated biomass change, we could conclude that *Ulva prolifera* entered the rapid proliferation period from May to June, reached the biomass peaks after developing for approximately 30 days, died out rapidly in July, and disappeared before August. In a few years, such as in 2009 and 2016, the trend of *Ulva prolifera* biomass exceeded the trend of its coverage area. The coverage area reached a maximum approximately 15 days after the biomass of *Ulva prolifera* reached its peak.

The simulation indicated that the biomass form was not comprised of a single change. In general, the biomass change form can be divided into two types. The first is the double-peak distribution form represented in 2011 and 2017, and the second is the single-peak distribution form shown in other years.

3.2 *Impact of green tide outbreaks on nutrient balance in the Yellow Sea*

According to the model calculation, the year with the most DIN and DIP uptake by *Ulva prolifera* was 2013, with DIN and DIP uptake of 3,850 tons and 110 tons, respectively. The year with the least DIN and DIP uptake by *Ulva prolifera* was 2017, with an uptake of 90 tons and 3 tons, respectively. Regarding the quality of the absorbed DIN, the disasters were more severe in the four years when the DIN absorption was more than 2,500 tons, while the disasters in 2009, 2010 and 2017 were less severe with less than 500 tons of DIN absorption. From the perspective of annual inflows and expenditures, green tide outbreaks have a relatively small impact on yearly nitrogen and phosphorus changes, but the summer outbreak of *Ulva prolifera* had a relatively large impact on the nutrient salt balance of the sea where it was located, and considering that the green tide was mainly distributed in the surface layer of seawater, the impact of the outbreak on the sea where it is located may be even greater.

4 Future Plans

1. Investigating the role of wind and current on *Ulva prolifera* drift through numerical experiments.
2. Discuss the reasons for differences in biomass of *Ulva prolifera* through sensitivity experiments.