ANALYSIS OF THE EFFECT OF GRID RESOLUTION ON ENVIRONMENTAL DNA MODELING

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1. INTRODUCTION

Environmental DNA (eDNA) dynamics in marine waters are dependent on the distribution of aquatic species and water transport. The eDNA physical properties are assumed to be uniform in each grid cell and its chemical properties are represented by concentration (mass per volume) in numerical Eulerian grid models. Hence, it is important to determine the optimal grid resolution, both horizontal and vertical. The effect of grid resolution on eDNA particle tracking has not been quantified in any study, as far as the authors are concerned. The horizontal and vertical grid resolutions used over the computational domain affects model input data, and transport and diffusion parameters. Meteorological simulations studies found out that higher spatial resolution improved results, however, for pollutant simulations, higher grid resolution may not result in significant improvements in results (Bricheno et al. 2013; Mircea et al. 2016; D'Isidoro et al. 2013; Miyakoda et al. 1971; Wickett, Caldeira, and Duffy 2003; Yin and Seo 2016). This study examines the effects of grid resolution of a three-dimensional hydrodynamic model and a particle tracking model on transport and distribution of eDNA.

2. METHODOLOGY

The model is applied to a simplified bay model with a parabolic bathymetry having a maximum depth 6 m at the center and a minimum depth 0.5m along the circumference. Three grid resolutions representing, (a) Case 1, low horizontal and vertical resolutions (15m horizontal grid and 5 vertical layers), (b) Case 2, low horizontal resolution and high vertical resolution (15m horizontal grid and 10 vertical layers), and (c) Case 3, high horizontal resolution and low vertical resolution, (5m horizontal grid and 5 vertical layers) were used for sensitivity analysis. Delft3D FLOW, a three-dimensional hydrodynamic (and transport) model is used to calculate non-steady flow and transport phenomena resulting from tidal forcing. A particle tracking model is used to determine the transport and distribution of eDNA from the point of release. The flow simulation results from Delft3D FLOW module are used by the particle tracking model to simulate the transport of eDNA. The particles in each grid cell volume are then counted, and the path taken by each particle is traced, to determine temporal and spatial variation of eDNA particles. Particles are released every 10 minutes from three particle sources (Fig. 1). The bay is divided into 235 equispaced grid points, and every grid point represents the center of an observation point. The depth of observation is from 1m to 3m below surface level, and horizontal grid is 2m × 2m, hence the observation point is 2m × 2m × 2m.

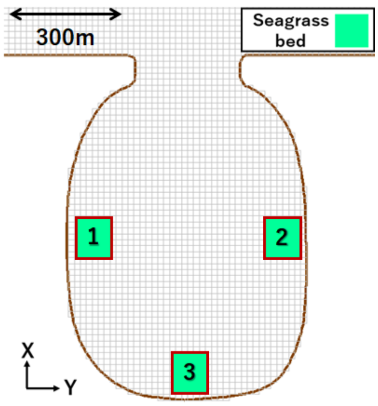

Fig. 1 The computational domain showing location of seagrass beds

3. RESULTS AND DISCUSSION

The effects of grid size on the temporal and spatial variation of flow patterns and magnitude, and particle distribution were studied. The differences between the three grid resolutions for flow patterns and magnitude are, in many respects, not significant. Fig. 2 show a snapshot of flow pattern at high tide for layers 2 (Fig. 2a, c) and 3 (Fig. 2b). The simple nature of the bay and bathymetry may explain these flow characteristics.

The analysis of particle distribution was to understand the effect of grid resolution on the total particles passing through an observation station. It also analyse the probability that particles passing through a station were released from a certain location. The distribution of total particles passing through each station is shown in Fig. 3. These results show that in Cases 1 and 2 (Fig. 3a, b), there is a high concentration of particles in the stations

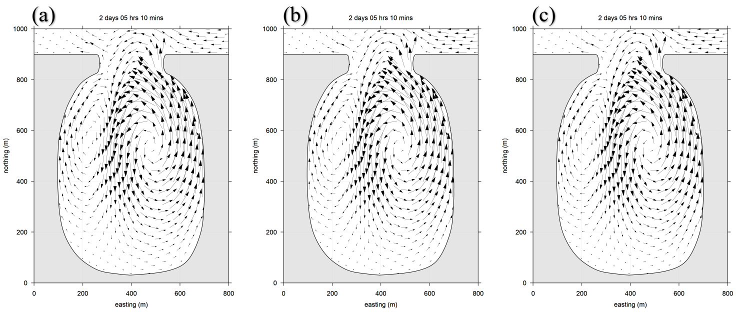

Fig. 2 Snapshot of flow patterns at high tide, (a) Case 1, (b) Case 2, 10 layers, (c) Case 3

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1-40, close to seagrass bed 3. In Case 3, there are fewer particles in the stations 1-40 than other cases indicating that the circulation is not almost localized to this region when fine grid resolution is used (Fig. 3c). The non-localized circulation indicates an increase in current velocity with increased grid resolution.

The distribution of particles released exclusively from seagrass bed 1 (Fig. 1, Fig. 4) show significant similarities between Cases 1 and 3, and significant differences between Cases 1 and 3, and Case 2. The distribution of particles released exclusively from seagrass bed 3 were similar for Cases 2 and 3, and different from Case 1 (Fig. 5). With fine horizontal grid resolution or fine vertical grid resolution, particles from seagrass bed 3 are occasionally transported to towards the bay mouth (stations 230-235). However, due to circulation patterns, particles released from seagrass bed 3 are concentrated around the release point and particles from seagrass beds 1 and 2 are distributed almost all over the bay in all the cases.

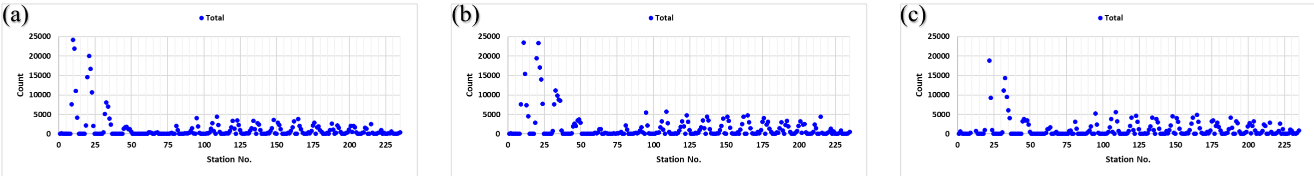

Fig. 3 Total times particles from seagrass bed 1 exclusively appeared to a station, (a) Case 1, (b) Case 2, 10 layers, (c) Case 3

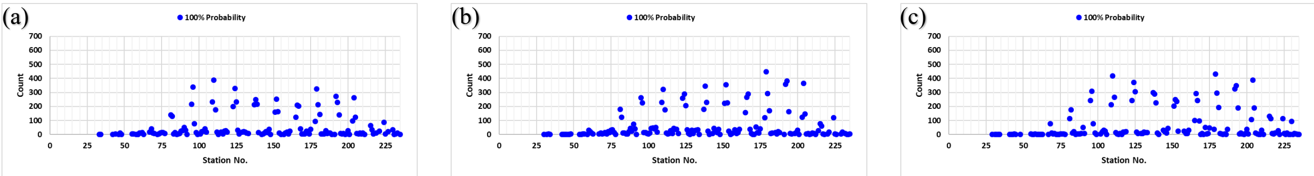

Fig. 4 Total times particles from seagrass bed 1 exclusively appeared to a station, (a) Case 1, (b) Case 2, 10 layers, (c) Case 3

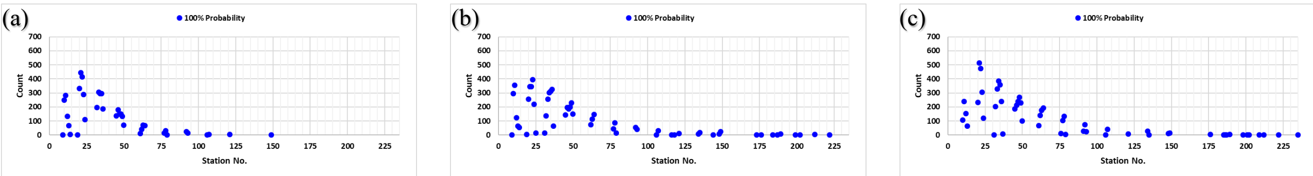

Fig. 5 Total times particles from seagrass bed 3 exclusively appeared to a station, (a) Case 1, (b) Case 2, 10 layers, (c) Case 3

4. CONCLUSIONS

The simulation results of particle tracking showed that the grid resolution, to some extent, affects the flow path, and eDNA transport resulting in biased temporal and spatial distribution of the eDNA particles. To ascertain the optimum horizontal/vertical grid resolution which will give the most accurate eDNA transport results, a study of a real situation with observed results for comparison is necessary.

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