ANALYZING THE EFFECTS OF WIND ON ENVIRONMENTAL DNA DISTRIBUTION IN SIMPLE BAYS

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1. INTRODUCTION

Environmental DNA (eDNA) is useful for monitoring of aquatic species, hence it is important to study the dynamics of eDNA in marine waters. Wind wave-induced movement of the water is one of the physical processes responsible for transport of suspended and dissolved substances, including eDNA particles (hereinafter particles) from seagrass beds (Nakata & Hirano, 1988; Smith et al., 1999). Wind speed and direction can affect the net flow, and moderate wind can reverse tidal flow (Colosimo et al., 2020). Wind wave-induced movement can affect the tide-induced velocities and transport of suspended matter (Colosimo et al., 2020; Franzen et al., 2019). This study examines the effect wind speed and direction on the transport and distribution of seagrass eDNA particles and discuss the probable effect of the prevailing winds on the design of monitoring network. Three major goals of the study: (i) studying the interaction between wind wave-induced flow and tidal currents; (ii) understanding how the wind modifies the flow; and (iii). understanding the effect of the modified flow on the number and distribution of seagrass eDNA particles.

2. METHODOLOGY

The model is applied to a hypothetical bay model with a parabolic bathymetry having maximum depth 7.5m at the center (Fig. 1). The bay is 1035m wide and 420m long. The bay mouths are 105m wide. The grid resolutions are as follows, (a) horizontal resolutions (15m grid), (b) vertical resolution (10 vertical layers). Two cases of numerical simulations were conducted. The first case uses Delft3D FLOW, a three-dimensional hydrodynamic (and transport) model to calculate non-steady flow and transport phenomena resulting from tidal forcing only (hereinafter tidal flow). The second case uses Delft3D-FLOW and Delft3D-WAVE to calculate tidal and wind wave-induced flow (hereinafter wind wave-induced flow). Both tide and wind data are real measurements in the area the simple bay was set. The hydrodynamic model results of water level, and velocities are passed on to the particle tracking model where they are used for calculating the advective transport of eDNA particles in the water. Particle tracking simulation of eDNA particles is then run particle injections at high and low tides. Almost 5600 particles were injected each time and are released near the bottom, realist release point of seagrass detritus. The number of eDNA particles are determined at 172 observation points equally distributed all over the bays. The depth of observation point is 2m × 2m × 2m, with sampling depth being from 1m to 3m below surface level. All the observation grid cells are of the same volume. On each sampling occasion, data on the wind speed and direction is used to analyze the role of wind speed and direction in the transport and distribution of eDNA particles.

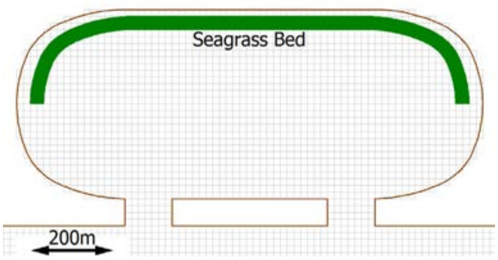

Fig. 1 The computational domain showing location of the seagrass bed

3. RESULTS AND DISCUSSION

The wind rose for the month of May 2020, time series of wind speed and direction and water level at the open boundary are shown in Fig. 2. Based on the wind rose in Fig. 2(a) it is noticed that for the month of May 2020, the dominant wind direction is West-North-West and East-South-East. Fig. 3 show the flow patterns on May 11th, 2020 at 07:00am (Fig. 3(a) & (b)) and on May 12th, 2020 at 01:00am (Fig. 3(c) & (d)), which corresponds with high tide and low tide at the open boundary, respectively. The flow patterns generated by tidal flow are almost symmetrical (Fig. 3(a) & (c)) whilst the flow patterns generated by wind wave-induced flow are prominently influenced by wind speed and direction (Fig. 3(b) & (d)).

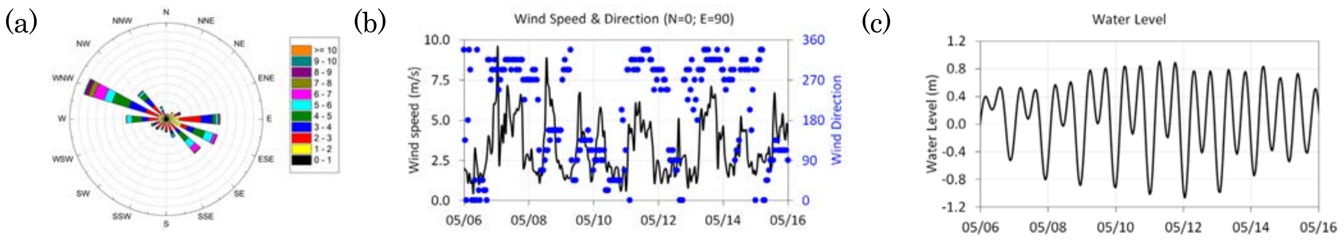

Fig. 2 Time series: (a) Wind rose, (b) Wind speed and direction, (c) Water level

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The time series of the total number of particles injected on May 6th, 2020 and observed at all observation points is shown in Fig. 4. The results show that more particles are observed under tidal flow conditions as compared to wind wave-induced flow conditions. Under tidal flow, particles tend to circulate in the bay and under wind wave-induced flow, the particles are transported out of the bay. In the wind wave-induced flow case, the particles are quickly transported out of the bay due to predominantly north-westerly winds around the May 7th, 2020 (Fig. 2(a)). The time series of the total number of particles for the tidal flow is almost constant. Two days after particle injection the total number of particles begins to fluctuate at almost constant rate in rhythm with flood and ebb tides (Fig. 4(a)). However, the flow velocity is greatly modified by wind which in turn influences the transport and distribution of particles (Fig. 4(b)). The dependency of eDNA particles transport on wind speed and direction is related to the hydrodynamics and the number of particles.

Fig. 5 show the maps of the distribution of the observed total number of particles injected on May 6th, 2020. In the tidal flow case, high number of particles is observed at locations with low flow speed and vice versa (Fig. 5(a)). The particles are almost evenly distributed across the bay in the wind wave-induced flow case (Fig. 5(b)). The particles are pushed towards the east by predominantly westerly winds. There are few particles observed at the bay mouths in both cases because of the restriction, the flow speed is high as shown in Fig. 3. The particles that approach the bay mouths are quickly transported out of the bay or into the bay. In both cases, the results suggests that the center of the bay is the best water sampling location.

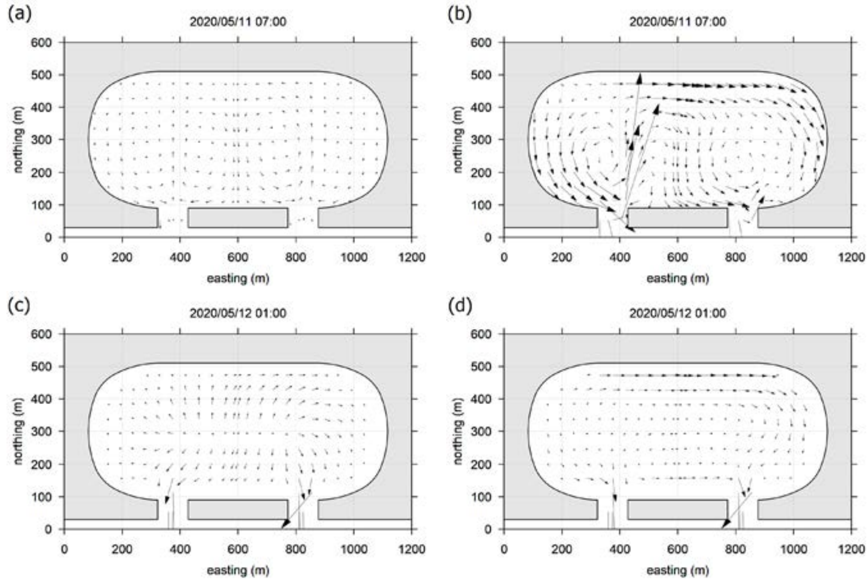

Fig. 3 (a & c) Tidal flow patterns and (b & d) wind wave-induced flow patterns

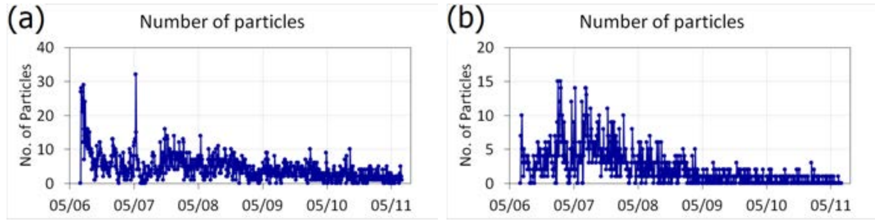

Fig. 4 Time series of the total number of particles, (a) tidal flow, (b) wind wave-induced flow

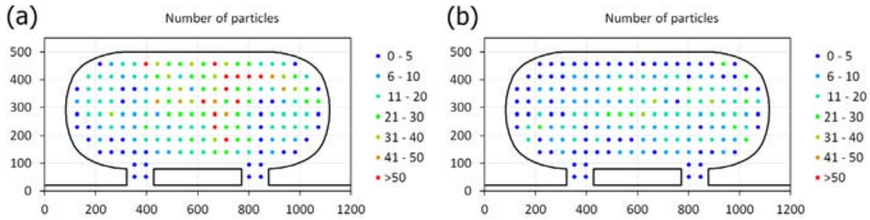

Fig. 5 Map of the distribution of the total number of eDNA particles, (a) tidal flow, (b) wind wave-induced flow

4. CONCLUSIONS

Water levels, flow, and the transport and distribution of eDNA particles were simulated. Based on the simulations, tide-induced flow and wind wave-induced flow were investigated and their influence on eDNA particles transport and distribution. The study shows the crucial role of wind in the eDNA particles dynamics and the generation of wind wave-induced flows enhancing tide-induced advection of eDNA particles, ultimately affecting their transport and distribution.

REFERENCES

Colosimo, I., de Vet, P. L. M., van Maren, D. S., Reniers, A. J. H. M., Winterwerp, J. C., & van Prooijen, B. C. (2020). The impact of wind on flow and sediment transport over intertidal flats. *Journal of Marine Science and Engineering*, *8*(11), 1–26. https://doi.org/10.3390/jmse8110910

Franzen, M. O., Muelbert, J. H., & Fernandes, E. H. (2019). Influence of wind events on the transport of early stages of Micropogonias furnieri (Desmarest, 1823) to a subtropical estuary. *Latin American Journal of Aquatic Research*, *47*(3), 536–546. https://doi.org/10.3856/vol47-issue3-fulltext-15

Nakata, H., & Hirano, T. (1988). Wind Effects on the Transport of Red Sea Bream Larvae from a Coastal Spawning Ground Adjacent to Shijiki Bay. In *Nippon Suisan Gakkaishi (Japanese Edition)* (Vol. 54, Issue 9, pp. 1545–1552). https://doi.org/10.2331/suisan.54.1545

Smith, P., Carroll, C., Wilkins, B., Johnson, P., Nic Gabhainn, S., & Smith, L. P. (1999). The effect of wind speed and direction on the distribution of sewage-associated bacteria. *Letters in Applied Microbiology*, *28*(3), 184–188. https://doi.org/10.1046/j.1365-2672.1999.00507.x