Editorial

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Editorial: Coastal protection provided by ecosystems: Observations and modeling across scales

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Editorial on the Research Topic:
Coastal Protection Provided by Ecosystems: Observations and Modeling Across Scales

This editorial summarizes the contributions to the Frontiers Research topic "*Coastal Protection Provided by Ecosystems: Observations and Modeling Across Scales*", established under the Frontiers in Marine Science – Oceans Solutions Journal.

Coastlines are subject to impacts of waves and currents, which drive risks of shoreline erosion and flooding of adjacent low-lying land. Increased risks are expected due to sea level rise, increasing storm intensity and frequency, land subsidence, and population growth. In this context, growing interest in how coastal ecosystems attenuate energy from waves and currents has motivated the implementation of nature-based solutions (NBS) for coastal protection. Although modeling and observations are already informing NBS, new predictive tools and methodologies are still needed to estimate the level of protection they provide under varied environmental and ecosystem conditions, to guide implementation of NBS as integrated parts of coastal protection practices. A first step to ensure proper implementation of NBS, is to better understand and parameterize the main processes involved in flow-ecosystem interactions. To this end, field and laboratory studies have been carried out to quantify the degree to which ecosystem properties induce hydrodynamic energy attenuation. In addition, numerical models, validated by field and laboratory data, provide tools to estimate such attenuation capacity. However, challenges remain in directly applying these findings in coastal protection practice. Specifically, a deeper understanding of how energy attenuation varies with local flow conditions and ecosystem properties remains crucial to facilitate the prioritization of NBS for coastal adaptation.

The main goal of this Research Topic is to highlight efforts to more accurately estimate the coastal protection service provided by ecosystems such as seagrasses, marshes, and mangroves, by analyzing their interaction with the flow, collecting novel data, and developing new predictive models based on local flow and ecosystem properties. The set of publications within this Research Topic focuses on bridging fundamental gaps in our knowledge of protection services provided by coastal ecosystems. Specifically, these works analyze fundamental aspects such as the interaction of the flow with different vegetated ecosystems in the laboratory and in the field, methods to define vegetation parameters, and a review of the reduction of coastal flood risk provided by mangroves.

Kelty et al. investigated the potential of *Rhizophora* mangrove forests of moderate cross-shore thickness to attenuate wave energy by means of an experimental study. By using an idealized prototype-scale forest, they analyzed wave height decay rates and drag coefficients. They compared their results to two previous reduced-scale studies finding a good agreement between all of them. Finally, using the combined data set of the three studies, the authors proposed a new equation to estimate the drag coefficient as a function of the Reynolds number. The results and formula obtained in this study can improve engineering guidelines for the use of mangroves in coastal wave attenuation.

Kalloe et al. focuses on the comparison of different methods to quantify the frontal area of a polar willow forest, testing the suitability of the methods for predicting wave attenuation by numerical modelling. To verify the numerical simulations, the authors compare the results with laboratory tests, highlighting that the different methods of quantifying frontal area led to significant differences in the estimation of wave attenuation. This study highlights the importance of indicating the method selected to obtain reliable estimates of frontal area and, consequently, reliable predictions of wave attenuation.

Möller et al. conducted a field study to measure transformation processes of wind generated waves in coastal reed beds. The study quantifies wave energy attenuation in reed beds as a function of local flow conditions and ecosystem properties. Such effects are not currently well understood across a variety of ecosystem types and therefore not well captured in the parameterization of vegetation-induced drag. Wave attenuation is shown to be significantly affected by seasonal variations in vegetation density. The study highlights the importance of year-long empirical field observations for a more complete understanding of the biogeomorphological feedbacks operating on shallow vegetated coasts.

Schaefer and Nepf presents an experimental study to examine the impact of waves on the vertical structure of time-averaged current, Reynolds stress, and turbulent kinetic energy (TKE) under combined wave-current conditions interacting with an artificial seagrass meadow. They analyze different ratios of wave velocity to current velocity finding differences in the resultant time-averaged variables under study. The study proposes a modified hybrid model for wake production of TKE in a flexible canopy under combined wave-current conditions including different wave-current regimes.

Villanueva et al. also focuses on the analysis of the relative influence of waves and currents on seagrass meadows under combined wave-current conditions by conducting laboratory tests. The study examines velocity profiles, Reynolds stresses and turbulent kinetic energy (TKE) considering different wave-current velocity ratios and analyzing the contribution of waves and current to the resulting hydrodynamic field. This study also proposes a modified hybrid model for TKE wake production in flexible canopies subjected to combined flows.

Gijsman et al. present a critical review of the coastal protection benefits provided by mangrove forests, and provide guidelines for implementing mangroves into nature-based coastal protection strategies. Their work highlights uncertainties, not only in the functionality of mangroves to reduce flood and erosion risks, but also in their persistence during and after disturbance events such as storms and due to stress factors like sea level rise. To reduce these uncertainties, they propose priority areas for scientific research on mangrove functionality and persistence, and suggest adaptive management approaches combined with appropriate engineering interventions to enhance mangrove functionality and persistence for nature-based coastal protection.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

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