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Editorial: Local hydrodynamics of benthic marine organisms

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Editorial on the Research Topic
Local hydrodynamics of benthic marine organisms

This Research Topic presents new studies on the local hydrodynamics of the mostly sessile, littoral marine organisms that occupy the ocean floor. New capabilities in experimental measurements and computations have allowed researchers to take a closer look at the detailed hydrodynamic processes that mediate the relationship between marine organisms and the surrounding ocean environment and may provide the key to building sophisticated new data-driven models of group and individual organismal behavior using highly resolved *in situ* and *in silico* measurements.

The studies collected in this Research Topic add to the body of knowledge of detailed descriptions of the flow fields around several types of marine organisms. The studies span the range of benthic marine organism kingdoms (plant and animal) at various scales and levels of mobility. They include sessile macroalgae and macroalgal assemblages, calcifying organisms, and seagrass meadows, as well as the transitionally mobile (mobile, but typically settled) ciliated microzooplankton, and fully mobile cnidarians. While marine organisms behave in complex ways that respond dynamically to changing ocean conditions, the presence of predators, food availability, the timing of reproductive cycles, and other factors, the studies presented here have mostly sought to characterize the hydrodynamics of the organisms studied under typical conditions.

The articles contained in this Research Topic not only cover a broad range of organisms but use a broad range of research approaches. Most of the studies investigated the hydrodynamics of marine organisms and ecosystems using experimental approaches. Kregting et al. used acoustic Doppler velocimetry (ADV) field measurements to assess the flow speed and turbulence within and above natural macroalgal canopies. Neto et al. used ADV and optical backscatter sensors (OBS) to investigate how a seagrass meadow modified the near-bed mean and wave-driven flows in a low-energy environment. Wandel and Holzman used particle tracking velocimetry (PTV) to investigate tintinnid feeding flow and behavior. Battista et al. investigated the hydrodynamics of *Cassiopea*, a genus of upside-down jellyfish, using three-dimensional (3D) PTV. Shavit et al. used underwater particle image velocimetry (PIV) to measure the flow field above the tentacles of

Dipsastraea favus and compared the flow field when tentacles were contracted and extended. Battista et al. also used computational methods in their study. They employed 3D immersed boundary simulations to characterize the flow generated by *Cassiopea*. The varied approaches used in these studies provided important insights into the mechanistic and behavioral basis of flow interactions in marine ecosystems, and their importance for ecosystem function, organismal processes, and sediment resuspension.

Kregting et al. performed acoustic Doppler velocimetry (ADV) field measurements to assess the flow speed and turbulence within and above natural macroalgal canopies at two sites and two depths in order to assess the variation of flow speeds and turbulent kinetic energy (TKE) as a function of canopy height and the percent coverage of functional forms. Filamentous macroalgal groups made up the greatest proportion (75%) at both sites and depths, while foliose groups were more prevalent at 3 meters than at 6 meters at both sites. They found significant damping of both the mean flow and turbulence by the macroalgae. Irrespective of background flows, depth, or site, flow speeds within the canopies were reduced by approximately 90% compared to above the canopy. And the TKE within the canopies was reduced by up to two orders of magnitude compared to above the canopies, with higher levels of TKE within the canopy at 3 meters depth, compared to 6 meters. The authors cite the strong flow modulation reported here, along with the local modulation of the pH of the seawater in macroalgal assemblage ecosystems, to highlight their potential as refugia for vulnerable calcifying species, shielding them from ocean acidification.

In their study, Neto et al. used ADV and optical backscatter sensors (OBS) to take field measurements that investigated how a seagrass meadow modified the near-bed mean and wave-driven flows in a low-energy environment, and to assess how this flow modification affected the suspended sediment concentration (SSC). They measured the mean and turbulent flow structure and estimated the SSC using the OBS measurements, within both a seagrass canopy and over an adjacent bare bed. The seagrass canopy was a *Posidonia* seagrass meadow with a shoot density of 400 ± 88 shoots per square meter. They found that the seagrass meadow was highly effective in attenuating current flows, with the current velocities within the seagrass canopy being, on average, just 35% of the velocity above the canopy; but much less effective at attenuating wave-driven oscillatory flows, with near-bed values being 83% of those above the canopy, on average. Critically, they found that sediment resuspension over seagrass meadows would be overestimated by assuming that the flows measured above a seagrass meadow are representative of those responsible for initiating sediment transport, as had been assumed in previous laboratory studies. Their results highlight the importance of measuring hydrodynamic processes within seagrass canopies for predicting the role seagrass meadows play in regulating sediment resuspension, which is important for water quality, coastal protection, reducing sediment erosion, and stabilizing seabeds.

Tintinnids are a type of microzooplankton that settle on marine snow and other aggregates, using cilia to create a feeding current that draws particles toward their mouth. However, it is unclear how they choose their prey. In their study, Wandel and Holzman used particle tracking velocimetry (PTV) to investigate tintinnid feeding flow and behavior. They found that the speed of feeding currents is influenced by the cilia beat frequency, which individual tintinnids can modify during foraging, causing the flow speed to increase or decrease up to three-fold within seconds. Tintinnids were selective throughout the feeding sequence, preferring larger prey initially but later choosing spherical over prolate prey. The authors also discovered that tintinnids can change their cilia kinematics, affecting their encounter rates, outcome, and handling. This research provides new insights into the mechanistic and behavioral basis of tintinnid feeding selectivity.

The study by Battista et al. investigated the hydrodynamics of *Cassiopea*, upside-down jellyfish that rest against the substrate with their oral arms extended upward. Although the pulsation of jellyfish bells has been studied extensively, it is unclear how the presence or absence of the substrate affects the flow patterns generated by *Cassiopea* medusae. To isolate the effect of the substrate, the authors used 3D particle tracking velocimetry and 3D immersed boundary simulations with the oral arms removed. The experimental results were used to validate the numerical simulations, which showed that the presence of the substrate enhances the generation of vortices and increases the upward velocities of the resulting jets. Additionally, the presence of the substrate creates a flow pattern where the water volume within the bell is ejected with each pulse cycle. The results suggest that positioning the upside-down jellyfish against the ocean floor is beneficial for increasing vertical flow and the volume of water sampled during each pulse.

In their study, Shavit et al. investigated the impact of the flow field on corals and other benthic organisms, and its effect on their biological processes. The absence of flow can reduce nutrient supply, photosynthesis, and prey capture, yet there have been few *in situ* studies on the hydrodynamics at the scale of coral polyps and their tentacles. The authors used underwater particle image velocimetry (PIV) to measure the flow field above the tentacles of *Dipsastraea favus*, comparing the flow field when tentacles were contracted and extended. Their results show that when the tentacles are extended, a mixing layer is formed above the coral, reducing velocities between the tentacles, increasing resident time, and developing velocity instabilities around the tentacle tips. The relative velocity fluctuations were found to increase by up to 3.5-fold compared to the contracted state of tentacles. This creates a high mixing environment around the distal ends of the tentacles, where there are acrospheres containing high concentrations of nematocytes. These findings can help explain the prevalence of acrospheres in benthic cnidarians and enhance our understanding of biological processes in corals and other benthic organisms related to feeding, growth, and mortality.

In the final study in this Research Topic, Koehl and Daniel investigated the biomechanical and hydrodynamic effects of encrusting epibionts on macroalgae, and of flexible hosts on epibiotic bryozoans, using blade-like red algae (*Mazzaella splendens*) and encrusting bryozoans (*Membranipora membranacea*). They measured flows using electromagnetic meters and other experimental methods. The authors found that passive flapping by algae in wave-driven ambient flow enhanced renewal of water near hosts and epibionts, while wave exposure and the presence of a surrounding canopy of flexible algae altered the locations along algal blades where bryozoans encountered the highest time-averaged boundary shear velocities. The hydrodynamic forces on flexible algae moving back and forth with the water were lower in waves than in unidirectional flow. The presence of bryozoan epibionts increased hydrodynamic forces on host algae by affecting their reconfiguration in moving water. Encrusting bryozoans increased the flexural stiffness of algal blades, but the elastic modulus, extensibility, and strength of the blade tissue were unaffected by bryozoan epibionts. However, algal blades were more extensible and stronger than bryozoans, so bryozoans fractured or popped off stretched algae. Finally, the authors found that algae in rapid-flow habitats had few epibionts, and encrusted algae transplanted from a protected to a wave-exposed habitat lost their epibionts. These findings provide insights into the complex interactions between macroalgae and their epibionts and the effects of hydrodynamics on these interactions.

A common theme in the research presented here was the ability of mostly sessile marine organisms to interact with the surrounding environment at small scales relative to their extent or body size, to their benefit. From water renewal due to passive flapping by algae, to enhanced mixing due to actively extended tentacles in corals, to food selection via actively varied cilia beat frequency in microzooplankton, the studies presented here show that small-scale flow-organism interactions mediate the relationship between marine organisms and the surrounding ocean environment in important ways.

Author contributions

AS, LM, MH, and SK contributed to the editorial. AS wrote the editorial. SK and LM gave feedback on the finalized version. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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