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Effect of oyster recruitment on local roughness and turbulent flow field at intertidal restored oyster reefs

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Oysters are recognized as ecosystem engineers that constitute vital parts of biodiverse and sustainable estuarine environments. Although their beneficial services are widely acknowledged, there has been a dramatic reduction in oysters population worldwide and current restoration projects aim to increase their numbers. In Mosquito Lagoon, on Florida's Atlantic coast, oyster restoration is accomplished by restoring existing degraded oyster reefs. Oyster reefs in Mosquito Lagoon are home to at least 150 additional species that include commercially and recreationally important fishes and invertebrates as well as foraging grounds for threatened/endangered birds. Successful restoration implies that oysters will recruit and the reef will obtain intricate structure similar to that of an intact natural oyster reef. Such a reef evolution will alter its surface roughness, which will subsequently affect the flow pattern and turbulence levels with significant implications on oyster recruitment and proliferation, sediment transport, and shoreline protection. The present experimental study compares flow and wave patterns on five oyster reefs with different surface roughness, in the intertidal environment of Mosquito Lagoon. These five oyster reefs comprise a natural, a degraded, and three restored oyster reefs with different restoration age (restored in 2014, 2016, and 2017). Three-dimensional flow velocity measurements were conducted on the oyster reefs with a Nortek Vectrino Profiler (3 cm velocity profile with 100 Hz sampling frequency) and at the adjacent channels with a Nortek Aquadopp acoustic Doppler current profiler (monitoring the whole water column at 2 Hz). Simultaneous measurements were conducted for wave height at these two locations, water level, and wind speed. Reef topography was measured with survey grade Global Navigation Satellite System (GNSS) equipment receiving real time kinematic (RTK) corrections from the Florida Permanent Reference Network. A Faro x330 laser scanner was used for detailed measurements of roughness elements, i.e. oyster clusters, that protrude into the flow. Two different sets of flow velocity measurements were collected for each reef during low- and high-water season, at the same location. For the former, flow measurements on the reefs were conducted at the bed vicinity, within the roughness sublayer defined by oysters, while for the latter measurements were conducted above the roughness sublayer. Results show that there is a gradual increase in turbulent kinetic energy dissipation rate with increasing restoration age, both for measurements within and above the roughness sublayer. This does not necessarily correlate with the number of live oysters counted on the reefs, due to their individual shape and random orientation. Reef roughness calculated with the aid of laser-scanner is compared to manual measurements of oyster shells that obstruct the flow and distributions of live oyster characteristics to infer appropriate measures for flow resistance and drag. Some of the well-known methodologies for bed shear stress calculation generate consistent results for the degraded reef; however, they derive a wide scatter for the natural reef, highlighting the insufficiency of current empirical formulae for bed shear stress estimation on oyster reefs.