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Exploring machine learning methods in advanced interpolation to unveil marine sediment geochemical signatures and physical composition: a case study in the Bay of Plenty, Aotearoa New Zealand

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The marine realm hosts many unique and vulnerable benthic habitats. From hard and gravelly to soft and muddy substrates, knowledge of the physical and geochemical composition of marine surficial sediments is vital for conservation efforts and assessing habitat sensitivity to anthropogenic pressures such as ocean acidification. However, sediment samples are sparse due to the vastness of the oceans and the high financial and time costs associated with collecting sediment samples during ocean voyages. Traditional interpolation methods such as Kriging struggle to accurately portray geospatial information due to the sparse and irregular sampling. Multivariate ensemble methods such as Random Forests, show more detailed results, however, is not geospatially aware.

In this study, a variant of Random Forests, Random Forests Spatial Interpolation (RFSI), is used to create detailed maps of geochemical signatures and physical properties such as grainsize, organic carbon, and inorganic carbon of surficial seafloor sediments of the Bay of Plenty, and wider Aotearoa New Zealand Exclusive Economic Zone. The ability of the RFSI machine learning method to leverage distance-based relationships results in geospatial geochemical maps with significantly improved grid resolution.

Geochemical distributions in the Bay of Plenty reveal patterns linked to regional geology. Sediments around Whakaari/White Island (andesite–dacite stratovolcano) show elevated Ni and Cu, while those near Tūhua/Mayor Island (peralkaline volcano) are enriched in Zn and Nb. Nearshore terrigenous sediments derived from North Island greywacke basement rocks display higher Si and Al contents. Strong positive correlations are observed between mud content and Rb and K concentrations (R^2 = 0.74 and 0.61, respectively). Mud also tends to correlate with organic carbon, suggesting that fine-grained sediments constitute an important organic carbon sink.

Detailed predictions of sediment geochemistry, grainsize, and organic carbon will be used to identify areas vulnerable to future ocean acidification and guide the selection of representative samples for equilibrium-leaching experiments. These experiments will test whether mud-rich, organic-rich sediments are less susceptible to releasing dissolved trace metals. The results of both macro-scale geospatial predictions and small-scale laboratory experiments combine to create a powerful framework to identify marine habitats that may be more vulnerable to future climate change impacts.