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Severe biological effects under present-day estuarine acidification in theseasonally variable Salish Sea

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ABSTRACT

Estuaries are recognized as one of the habitats most vulnerable to coastal ocean acidification due to seasonal extremes and prolonged duration of acidified conditions. This is combined with co-occurring environmental stressors such as increased temperature and low dissolved oxygen. Despite this, evidence of biological impacts of ocean acidification in estuarine habitats is largely lacking. By combining physical, biogeochemical, and biological time-series observations over relevant seasonal-to-interannual time scales, this study is the first to describe both the spatial and temporal variation of biological response in the pteropod Limacina helicina to estuarine acidification in association with other stressors. Using clustering and principal component analyses, sampling sites were grouped according to their distribution of physical and biogeochemical variables over space and time. This identified the most exposed habitats and time intervals corresponding to the most severe negative biological impacts across three seasons and three years.We developed a cumulative stress index as a means of integrating spatial-temporal OA variation over the organismal life history. Our findings show that over the 2014–2016 study period, the severity of low aragonite saturation state combined with the duration of exposure contributed to overall cumulative stress and resulted in severe shell dissolution. Seasonally-variable estuaries such as the Salish Sea (Washington,U.S.A.) predispose sensitive organisms to more severe acidified conditions than those of coastal and open-ocean habitats, yet the sensitive organisms persist. We suggest potential environmental factors and compensatory mechanisms that allow pelagic calcifiers to inhabit less favorable habitats and partially offset associated stressors, for instance through food supply, increased temperature, and adaptation of their life history.