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Oxygen dependence of visual function and ecology in marine larvae

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Vision is an essential and metabolically demanding (oxygen intensive) process for both vertebrates and invertebrates; in the marine environment this is true for active arthropods, cephalopods, and fish that possess complex eyes and 'fast vision' (high temporal resolution). Oxygen loss in the ocean, termed ocean deoxygenation, is occurring as a result of ocean warming effects on solubility and stratification, intensified upwelling, and increasing eutrophication. Additionally, both light and oxygen concentration exhibit strong gradients with depth in the ocean, particularly on highly productive margins with eastern boundary currents where the upwelling of low-oxygen water creates these steep gradients at shallow depths. This research examines the consequences of oxygen loss for visual function in larvae of different representative taxa and visual groups (e.g. crustaceans and cephalopods, compound eyes and simple eyes) that rely on vision for survival in their early life stages. Hypotheses that oxygen stress changes the physiological capability of the eye to respond to light and that the response is species-dependent are tested using electrophysiology experiments. Results show a marked effect of oxygen on the visual response to light stimuli, with visual decline of 10% of maximum response occurring even at 95 µmol/L oxygen concentration (6.6 kPa) in some species; oxygen values much higher than traditional physiological critical limits and definitions of hypoxia. Declines of visual function in invertebrates occur more strongly at high light intensities, indicating light intensity can become an additional stressor for upward-migrating species in habitat compression. The combined distribution of oxygen concentration and light levels in the water column that organisms are exposed to can be perceived as a *luminoxyscape*. Physiological limits of oxygen and light sensitivity for these species are compared with environmental data and used to calculate a species-specific 'critical luminoxyscape' where there are sufficient light and oxygen conditions that enable normal vision. Using data from hydrographic profiles obtained during quarterly cruises by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program since 1984, changes in the available critical luminoxyscape over time for these species are discussed and visual decline from oxygen and light stress is demonstrated to be an additional explanation for habitat compression from ocean deoxygenation.

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