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## How ocean deoxygenation affects fish: Implications of Gill-Oxygen Limitation Theory (GOLT)

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One of the expected responses of marine fishes to ocean warming is reduced growth and size, as supported by evidence from empirical data and theoretical modelling. The theoretical underpinning for fish shrinking is that the oxygen supply to large fish size cannot be met by their gills, whose surface area cannot keep up with the oxygen demand by their three-dimensional bodies. Although this logic has been recently challenged, it will be shown, in the context of Gill-Oxygen Limitation Theory (GOLT) that gills, because they must retain the properties of open surfaces, cannot avoid being limiting for fish growth. Also, besides explaining (1) the growth patterns of fish, a wide range of biological features of fish and other water-breathing organisms can be understood only when gill area limitation is used as an explanation, including (2) the decline of food conversion efficiency with size; (3) the size at which they reproduce; (4) why the fish of a given species are larger at the cold end of their distribution ranges; (5) why fish move into deeper/colder waters when they grow bigger; (6) why the growth and food conversion efficiency of farmed fish declines when oxygen supply is reduced; (7) why fish perform temperature-driven seasonal migrations; (8) why global warming induces poleward migrations; (9) why the otoliths of fish and the statoliths of invertebrates form clear daily rings in larvae and juveniles, but in adults; (10) many other phenomena that are never been elucidated before, or even perceived as requiring an explanation. The GOLT thus appears to have the potential of a powerful theory capable of acceleration progress in marine biology and limnology and the corresponding applied discipline, i.e., fishery science and aquaculture.

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