

## Overview Review

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# Persistent eutrophication and hypoxia in the coastal ocean

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## Abstract

Coastal eutrophication and hypoxia remain a persistent environmental crisis despite the great efforts to reduce nutrient loading and mitigate associated environmental damages. Symptoms of this crisis have appeared to spread rapidly, reaching developing countries in Asia with emergences in Southern America and Africa. The pace of changes and the underlying drivers remain not so clear. To address the gap, we review the up-to-date status and mechanisms of eutrophication and hypoxia in global coastal oceans, upon which we examine the trajectories of changes over the 40 years or longer in six model coastal systems with varying socio-economic development statuses and different levels and histories of eutrophication. Although these coastal systems share common features of eutrophication, site-specific characteristics are also substantial, depending on the regional environmental setting and level of social-economic development along with policy implementation and management. Nevertheless, ecosystem recovery generally needs greater reduction in pressures compared to that initiated degradation and becomes less feasible to achieve past norms with a longer time anthropogenic pressures on the ecosystems. While the qualitative causality between drivers and consequences is well established, quantitative attribution of these drivers to eutrophication and hypoxia remains difficult especially when we consider the social economic drivers because the changes in coastal ecosystems are subject to multiple influences and the cause–effect relationship is often non-linear. Such relationships are further complicated by climate changes that have been accelerating over the past few decades. The knowledge gaps that limit our quantitative and mechanistic understanding of the human-coastal ocean nexus are identified, which is essential for science-based policy making. Recognizing lessons from past management practices, we advocate for a better, more efficient indexing system of coastal eutrophication and an advanced regional earth system modeling framework with optimal modules of human dimensions to facilitate the development and evaluation of effective policy and restoration actions.