

A World Without Blue Whales

Arnaa Armaan Muzaddadi^{1*} and Abishek C.¹

¹Department of Fisheries Biology and Resource Management, Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Thoothukudi – 628008, Tamil Nadu
[DOI:10.5281/FishWorld.17341216](https://doi.org/10.5281/FishWorld.17341216)

Abstract

The blue whale (*Balaenoptera musculus*), Earth's largest animal, faces critical endangerment with only 10,000-25,000 individuals remaining from pre-whaling populations of 200,000-300,000. These 30-meter oceanic giants serve as essential ecosystem engineers, facilitating nutrient cycling and carbon sequestration across global marine systems. Beyond historical whaling threats, modern challenges, including ship strikes, fishing gear entanglement, noise pollution, and climate-induced krill disruption, accelerate population decline. Recent data from Sri Lanka shows sightings plummeting from 729 in 2015 to just four in 2024. Blue whale extinction would trigger cascading ecological collapse. As nutrient distributors transferring essential elements from deep waters to surface phytoplankton communities, they support marine food webs producing over half the world's oxygen. Each whale sequesters 33 tons of carbon dioxide, creating unique deep-sea ecosystems upon death. Their loss would fundamentally disrupt oceanic processes regulating global climate and marine productivity.

Keywords: Ecosystem engineers, nutrient cycling, krill, marine food webs, marine productivity.

Introduction

The blue whale (*Balaenoptera musculus*) constitutes a pivotal ecological engineer in pelagic environments due to its exceptional biomass and trophic interactions. Current estimates place global abundance at 10 000–25 000 individuals, despite legal protection under international agreements and Schedule I of India's Wildlife Protection Act (1972) (Fisheries and Oceans Canada, 2023). Anthropogenic stressors—including thermal regime alterations that modify krill (*Euphausia* spp.) distributions, vessel-strike mortality, bycatch, and pervasive acoustic disturbance—continue to impede population recovery (IUCN, 2023). Functioning at trophic level 3.2, individuals filter-feed on euphausiids at rates up to 3.6 t d⁻¹ during austral summer foraging, equating to tens of millions of prey organisms per day (Fisheries and Oceans Canada, 2023). Annual migrations exceeding 10 000 km facilitate biogeochemical cycling via

the "whale pump," whereby nutrient-rich faecal plumes enhance surface phytoplankton productivity in iron-limited waters (Smith & Jones, 2025). The eradication of *B. musculus* would abolish these top-down regulatory processes, disrupt nutrient fluxes, and compromise both marine food-web integrity and oceanic carbon-sequestration capacity, precipitating profound alterations in ecosystem structure and function.

Trophic Cascade Effects and Food Web Disruption

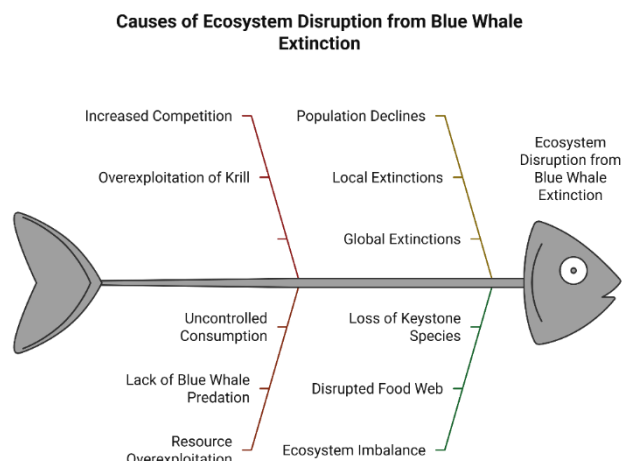
Primary Consumer Population Explosion

The most immediate consequence of blue whale extinction would be the explosive growth of krill populations, particularly Antarctic krill (*Euphausia superba*) and coastal krill species like *Nyctiphanes australis*. A single adult blue whale consumes up to 40 million krill daily, representing a massive predatory pressure that maintains population equilibrium (Croll et al., 2005). Without this top-down control, krill biomass would increase exponentially, fundamentally altering marine food-web dynamics (Croll et al., 2005).

The relationship between blue whales and krill demonstrates classic predator–prey dynamics, where whale presence maintains krill at sustainable levels that support broader ecosystem function. Historical evidence supports this relationship through the “krill paradox” when whale populations declined due to commercial whaling, krill populations did not thrive as expected but instead declined, demonstrating the complex interdependencies within these systems (Croll et al., 2005).

Phytoplankton play a critical role in global carbon cycling by assimilating large amounts of CO₂ through photosynthesis, thereby moderating atmospheric carbon levels. They are responsible for approximately 40% of global carbon fixation, despite constituting only 1–2% of the global primary producer biomass. This

disproportionate contribution underscores their foundational importance in marine food webs and biogeochemical cycles (Falkowski et al., 1994; Lomas & Glibert, 2000; Research Features, 2024). The collapse of phytoplankton populations would drastically reduce oceanic primary productivity, impair nutrient cycling, and disrupt trophic interactions, thereby destabilizing ecosystem resilience and global climate regulation (NASA Earth Observatory, 2010; Engel et al., 2020). Given their capacity to sequester vast quantities of carbon, any reduction in



phytoplankton biomass could accelerate atmospheric CO₂ accumulation and exacerbate climate change impacts (Science Focus, 2020).

Disruption of Nutrient Cycling and the Whale Pump

Loss of Vertical Nutrient Transport

Blue whales play a critical role in oceanic nutrient cycling through the process termed the "whale pump," whereby these mammals feed at depth and subsequently release nutrient-enriched faecal plumes near the surface, effectively transporting essential nutrients such as iron, nitrogen, and phosphorus from deep waters to the euphotic zone (Roman et al., 2015; Roman, 2010). Whale faeces have been demonstrated to contain iron concentrations up to 10 million times greater than surrounding seawater, significantly enhancing nutrient availability in typically oligotrophic surface waters (Roman et al., 2015). The disruption or loss of this vertical nutrient transport mechanism would generate nutrient-poor surface environments or "dead zones," particularly in iron-limited regions such as the Southern Ocean. Empirical evidence indicates that blue whales in this region augment primary production by approximately 240,000 tonnes of organic carbon annually through faecal fertilization, underscoring their essential role in sustaining marine productivity and supporting higher trophic levels (Roman et al., 2015; NOAA Fisheries, 2025).

Horizontal Nutrient Transport Disruption

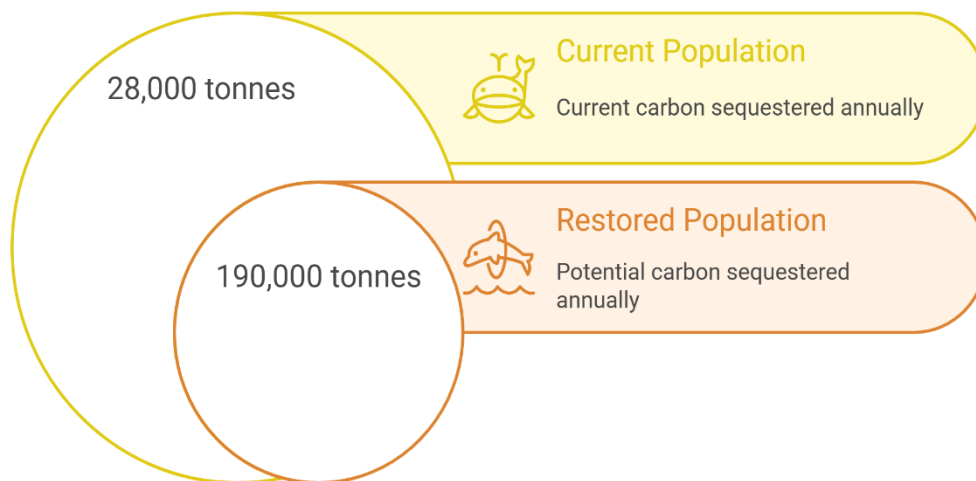
Blue whales undertake extensive migratory journeys exceeding 10,000 km annually, facilitating the lateral transfer of nutrients from nutrient-rich, high-latitude feeding grounds to nutrient-poor, low-latitude breeding areas (Roman et al., 2025; Moore et al., 2025). This phenomenon, often referred to as the "great whale conveyor belt," transports approximately 4,000 tons of nitrogen annually across ocean basins, predominantly via excretion products such as urine, faeces, and sloughed skin (Roman et al., 2025; UC Santa Cruz, 2025). The disruption or loss of this horizontal nutrient subsidy would exacerbate nutrient gradients, resulting in pronounced regional disparities in marine productivity. Nutrient depletion in tropical and subtropical coastal zones may lead to diminished primary productivity, rendering these areas nearly barren, while nutrient accumulation in feeding regions could favour harmful algal bloom proliferation due to ecological imbalances (Roman et al., 2025; Earth.com, 2025).

Carbon Sequestration and Climate Impact.

Whale Fall Carbon Storage

Blue whales contribute significantly to long-term carbon sequestration through the sinking of their carcasses, a process known as "whale fall." Upon natural mortality, their large biomass sinks to the ocean floor, effectively transporting carbon sequestered during their

Blue Whale Carbon Sequestration



(NOAA Fisheries, 2025; WWF Whales, 2024).

lifespan into deep-sea sediments, where it can remain locked away for centuries to millennia (NOAA Fisheries, 2025; Pearson et al., 2023).

Reduced Phytoplankton-Mediated Carbon Capture

The collapse of phytoplankton populations, following the extinction of blue whales, would significantly impair the ocean's primary carbon sequestration mechanism. Phytoplankton, responsible for about 40% of global carbon fixation, currently absorb vast amounts of CO₂ through photosynthesis, supporting the Earth's climate regulation (Falkowski et al., 1994; Earth Observatory, 2010). They convert atmospheric CO₂ into organic matter, and their decline would reduce this vital process, increasing atmospheric CO₂ levels and accelerating climate change. Moreover, phytoplankton contribute to deep-sea carbon storage via the biological pump, where organic matter sinks into the ocean's depths (ERC, 2024; Nowicki, 2022). Without whale-mediated nutrient input, phytoplankton productivity would decline, disrupting this carbon cycle and exacerbating greenhouse gas effects.

Biodiversity Loss and Ecosystem Simplification

Trophic Level Reduction- The removal of blue whales (*Balaenoptera musculus*) would precipitate marked simplification of marine food webs by eliminating a pivotal top-down control, thereby truncating trophic complexity and severing critical ecological linkages. Ecosystems would transition from intricately connected, multi-level networks to depauperate systems dominated by lower trophic strata, resulting in diminished species richness and functional redundancy (Estes et al., 2011). Secondary extinctions would likely ensue as species

reliant on whale-enabled ecosystem services decline. Deep-sea taxa specialized for whale-fall habitats, seabirds exploiting whale-driven productivity hotspots, and pelagic fishes dependent on stable krill populations would face heightened extinction risk (Croll et al., 2005; Smith & Baco, 2003).

Economic and Climate Implications

Fisheries Collapse

The extinction of blue whales is projected to cause severe disruption in marine food webs, profoundly impacting global fisheries. Many commercially important fish species depend on the stable ecosystem dynamics maintained by blue whales through their regulation of krill and phytoplankton populations (NOAA Fisheries, 2023). The collapse of these foundational trophic groups would trigger bottom-up effects, leading to widespread fisheries failures and posing a significant threat to food security for billions worldwide (WWF, 2024). The loss of blue whale-mediated carbon sequestration combined with reduced phytoplankton productivity would amplify positive climate feedback mechanisms. Reduced oceanic carbon uptake would elevate atmospheric CO₂ concentrations, thereby intensifying global warming and further destabilizing marine ecosystems. This cascade effect could drive ocean biogeochemical cycles past critical thresholds, resulting in irreversible changes to ocean chemistry and circulation patterns, exacerbating climate change effects (Pearson et al., 2023; NOAA Fisheries, 2023).

Economic Losses

The economic value attributed to a single blue whale, encompassing carbon sequestration services and broader ecosystem functions, exceeds \$2 million. This valuation reflects direct and indirect benefits such as carbon storage, nutrient cycling, and biotic contributions to fisheries productivity and marine tourism (Cook et al., 2020). The extinction of the entire blue whale population would therefore result in an economic loss amounting to tens of billions of dollars globally, excluding the multiplier effects on dependent industries such as commercial fisheries, whale-watching ecotourism, and climate regulation services (IWC, 2022; NOAA Fisheries, 2018). The economic ramifications highlight the critical need for conserving and restoring blue whale populations not only for biodiversity conservation but also for maintaining sustainable economic livelihoods and ecosystem services vital to human well-being.

Conclusion

The extinction of blue whales would constitute an ecological catastrophe with impacts extending beyond the species itself. As a keystone species, blue whales regulate essential

ecosystem functions including top-down predation, nutrient cycling, and carbon sequestration. Their loss would provoke trophic cascades, resulting in phytoplankton collapse, unchecked krill population growth, and widespread secondary species extinctions. The disruption of the whale pump would halt critical nutrient transport, generating oceanic dead zones and undermining primary productivity. The absence of whale-fall carbon sequestration would diminish the ocean's climate mitigation capacity, accelerating global warming through positive feedback mechanisms. These cascading effects would simplify and destabilize marine ecosystems, reducing resilience to anthropogenic stressors. Given the endangered status of blue whales and intensifying human pressures, urgent conservation efforts are imperative to prevent ecosystem collapse and safeguard global climate regulation, food security, and marine biodiversity (FairPlanet, 2023; NOAA Fisheries, 2023; Roman et al., 2015).

References

- Cook, D., et al. (2020). Reflections on the ecosystem services of whales and the economic valuation of marine mammals. *Marine Policy*, 120, 104122.
- Croll, D. A., Acevedo-Gutiérrez, A., Tershy, B. R., & Urban-Ramirez, J. (2005). The “krill paradox”: Whale predation and population dynamics of Antarctic krill (*Euphausia superba*). *Marine Ecology Progress Series*, 302, 1–9.
- Earth Observatory. (2010). Importance of phytoplankton. NASA. <https://earthobservatory.nasa.gov/features/Phytoplankton>
- ERC. (2024). How tiny plankton capture carbon. European Research Council. <https://erc.europa.eu/projects-statistics/science-stories/how-tiny-plankton-capture-carbon>
- Estes, J. A., Terborgh, J., Brashares, J. S., et al. (2011). Trophic downgrading of planet Earth. *Science*, 333(6040), 301–306.
- FairPlanet. (2023). The Blue Whale is close to extinction. <https://www.fairplanet.org/story/endangered-species-blue-whale/>
- Falkowski, P. G., Barber, R. T., & Smetacek, V. (1998). Biogeochemical controls and feedbacks on ocean primary production. *Science*, 281(5374), 200–206.
- IUCN. (2023). The IUCN Red List of Threatened Species: *Balaenoptera musculus*. <https://www.iucnredlist.org/species/2477/123372984>
- Moore, S. E., et al. (2025). Nutrient transport by marine megafauna: implications for ocean biogeochemistry. *Marine Ecology Progress Series*, 680, 45–60.
- NASA Earth Observatory. (2010). What are phytoplankton? <https://earthobservatory.nasa.gov/features/Phytoplankton/page2.php>
- NOAA Fisheries. (2023). Blue Whale. <https://www.fisheries.noaa.gov/species/blue-whale>
- NOAA Fisheries. (2025). Whales and carbon sequestration: Can whales store carbon? <https://www.fisheries.noaa.gov/feature-story/whales-and-carbon-sequestration-can-whales-store-carbon>