(Hilário et al., 2015; Dasgupta et al., 2024). The organic enrichment from whale falls is a key driver of productivity in otherwise food-limited deep-sea environments (Butman et al., 1995; Smith and Baco, 2003; Dasgupta et al., 2024).

3.2 Enhancement of local biodiversity and creation of ecological hotspots

Whale falls act as biodiversity hotspots, supporting unique assemblages of macrofauna, including generalist scavengers, chemosynthetic fauna, and bone-specialist species. Many species found at whale falls are new to science or rarely observed elsewhere, and the presence of ecosystem engineers like Osedax worms increases habitat complexity and microhabitat diversity (Lucas, 2015; Shimabukuro et al., 2019; Shimabukuro et al., 2022). Studies show that whale-fall communities are distinct from those in surrounding sediments, with higher species richness and evolutionary novelty (Danise et al., 2014; Hilário et al., 2015; Lucas, 2015; Shimabukuro et al., 2019; Shimabukuro et al., 2022). These communities can persist for years, and some taxa exhibit interbasin distributions, highlighting the global significance of whale falls for deep-sea biodiversity (Shimabukuro et al., 2019; Shimabukuro et al., 2022).

3.3 Connection with other chemosynthetic environments

Whale falls share ecological and evolutionary links with other deep-sea chemosynthetic environments, such as hydrothermal vents and cold seeps. Many whale-fall specialists, including chemosymbiotic bivalves and polychaetes, are closely related to or shared with vent and seep communities (Levin et al., 2007; Bernardino et al., 2012; Duperron et al., 2013; Shimabukuro et al., 2019; Avila et al., 2023). Whale falls may serve as “stepping stones” for the dispersal of chemosynthetic fauna, facilitating gene flow and connectivity among spatially isolated habitats (Bernardino et al., 2012; Hilário et al., 2015; Shimabukuro et al., 2019; Avila et al., 2023). The similarity in community structure and reliance on chemosynthetic production underscores the role of whale falls in the broader network of deep-sea reducing ecosystems (Levin et al., 2007; Bernardino et al., 2012; Duperron et al., 2013; Avila et al., 2023).

Whale falls thus represent essential oases in the deep ocean, driving nutrient cycling, supporting high biodiversity, and connecting the patchwork of chemosynthetic habitats across the seafloor.

4 Whale Falls and Biogeochemical Cycles in the Deep Ocean

4.1 Role in carbon sequestration

Whale falls represent a significant mechanism for transferring organic carbon from the surface to the deep ocean. When a whale carcass sinks, it delivers a concentrated pulse of organic carbon to the seafloor. A single large whale can provide an input of organic carbon equivalent to thousands of years of background sedimentation rates (Sheehy et al., 2022). While soft tissues are typically recycled into the food web within about two years, the bones—especially when deposited at depths greater than 1000 meters—can persist for over a century, effectively sequestering carbon and removing it from atmospheric exchange. Restoration of cetacean populations could thus enhance carbon sequestration through increased whale-fall events, contributing to climate change mitigation (Sheehy et al., 2022).

4.2 Influence on sulfur, nitrogen, and phosphorus cycles

Whale falls create localized zones of intense microbial activity, particularly sulfate reduction and methanogenesis, which drive the sulfur cycle in deep-sea sediments (Goffredi et al., 2008; Treude et al., 2009). Sulfate-reducing bacteria break down organic matter, producing hydrogen sulfide that supports chemosynthetic communities similar to those at hydrothermal vents and cold seeps (Treude et al., 2009). Methanogenic archaea also thrive, establishing active methane cycles beneath whale falls (Goffredi et al., 2008). Additionally, cetaceans contribute to nitrogen and phosphorus cycling through the "whale pump"—the vertical and horizontal transport of nutrients via feeding and excretion—which enhances nutrient availability for phytoplankton and supports primary productivity in nutrient-limited waters (Sheehy et al., 2022). This nutrient cycling is crucial for sustaining deep-sea and surface productivity, with estimates suggesting that cetacean-driven processes recycle substantial amounts of nitrogen annually (Sheehy et al., 2022).