Plankton, the Great Migration, and Marine Snow

During World War II, sonar seemed to show parts of the sea floor moving up and down.[1] What was causing this? Plankton! Just after sunset, trillions of zooplankton rise to the surface of the ocean to feed, then retreat to deeper waters just before sunrise. This is called diel vertical migration and is likely the greatest synchronous migration on Earth in terms of biomass. Plankton are organisms that float and swim against currents with difficulty; their name comes from Greek for drifter. Nevertheless, plankton may travel hundreds of meters, responding to sunlight (or phases of the moon in polar winter or even cloud cover) and other cues.[2] Larger fish and animals also migrate. Some vertical migrations are seasonal.[3]

The ocean has layers.[4] Massive numbers of organisms live in the upper sunlit layer, including phytoplankton that carry out photosynthesis to convert the sun's energy and dissolved CO2 into biomass. Light is faint in the twilight zone, beginning at about 200 meters depth. Many zooplankton and fish lay low here during the day and migrate nightly to the surface for food, and back, which has the effect of transporting bodily carbon downward. Past the twilight zone, below 1000 meters, light is absent in the midnight zone, the abyss, and the deepest hadal zone extending to the bottom of trenches.[5]

Carbon is passed along the food chain from phytoplankton, to zooplankton that eat them, on up to fish, birds, and mammals. Organisms convert carbon to biomass (the stuff that makes up living things, e.g. leaves, muscle, fat), or excrete it as fecal pellets, or respire CO2 back to the sea. When creatures die their remains descend deeper into the ocean interior and are broken down by bacteria and microbes, releasing CO2. Fecal pellets, plankton, gooey aggregates, and other biological debris sink slowly toward the seabed as marine snow, which Rachel Carson called "the most stupendous snowfall on Earth."[6]

The transport of organic matter and carbon from the surface to deep ocean is called the biological pump. It works through three main pathways: gravitational settling of carbon in plankton and byproducts (marine snow), vertical migration, and mixing by currents. Most of the carbon bound up in biomass is consumed and recycled in the sunlit layer. Only about 10-20% of organic carbon escapes the sunlit zone, and only a tiny amount reaches the ocean bottom.[6] The deeper it goes, the longer carbon will be sequestered, but importantly, once the bits of carbon leave the surface layer, decades or even centuries may pass before the carbon can rise and escape into the atmosphere as CO2. The biological pump exports ~10 PgC/year from the surface ocean and sequesters 1300 PgC; the gravitational component contributes the most to this and mixing the least.[7]

Overall, the ocean has absorbed a quarter of CO2 emissions from fossil combustion and deforestation (and the natural land carbon sink has absorbed another quarter). Carbon is transported to deep sea by the biological pump and also two other ways. The solubility carbon pump involves global thermohaline circulation. Shells made by calcifying marine organisms will sink into sea floor sediment. However, forming calcium carbonate increases CO2, working against sea uptake of CO2 from the atmosphere.[8]

Plankton are a super diverse collection of organisms, including thousands of species from all kingdoms: viruses, bacteria such as Spirulina, fungi, foraminifera, copepods (small crustaceans), krill, fish larvae, salps, jellyfish, and more. They are mostly microscopic but siphonophores can be 50 meters long.[9] Climate change, pollution, and human activities are affecting plankton. As waters warm, plankton are moving towards the poles. There are shifts in the distribution of smaller plankton compared to diatoms and larger plankton that sink rapidly with their carbon.[10] Heat and too many nutrients promote bigger and more frequent harmful algal blooms.[11] Plankton are harvested as feed for agriculture and aquaculture and beset by pollutants including microplastics.

These weird and tiny creatures are at the root of the ocean food web, nourishing creatures all the way up to the blue whale, and they are key drivers of the ocean carbon sink. Here's a cheer for plankton!

REFERENCES

[1] Plankton with Erich Hoyt, Nov 2022, SeaCreatures podcast episode 36 (no transcript) (https://open.spotify.com/episode/3M8B0W4wZr3L0zu6yHhiIz?si=9jpJ1mIxRZ-FQJ6JNXunUQ). How the author of *Planktonia* got interested in plankton. (I haven't read the book, but the photos look great.)

[2] The ups and downs of a great vertical migration. Seo H, Dec 2021 (https://knowablemagazine.org/content/article/living-world/2021/up-downs-great-vertical-migration)

[3] Two hundred years of zooplankton vertical migration research. Bandara K et al, May 2021 (https://doi.org/10.1111/brv.12715)

[4] *The Blue Machine. How the ocean works.* Helen Czerski, 2023. The thin, warm upper layer is home to sunlight energy, but gravity gradually strips the surface layer of denser nutrients, which sink into colder, thicker layers below. I recommend this book for its clear writing and start-from-basics approach.

[5] Layers of the ocean. NOAA (https://www.noaa.gov/jetstream/ocean/layers-of-ocean) The ocean water column consists of epilagic (sunlight), mesopelagic (twilight), bathypelagic (midnight, starting at 1000 m depth), abyssopelagic (abyssal, at 4000 m), and hadalpelagic (hadal, 6000 m to trench bottoms) zones. The sunlit layer is also called euphotic or photic for its light, as opposed to the aphotic midnight and lower zones that lack light except from bioluminescent animals. The upper layer that is mixed by winds, waves, and currents is also called the mixing layer.

[6] The Ocean Twilight Zone Project. Woods Hole Oceanographic Institution. Buesseler K et al. No date but includes references from 2021 (https://twilightzone.whoi.edu/role-in-climate/). See also Dr. Ken Buesseler's very short video, Twilight zone, Oct 2024 (https://www.youtube.com/shorts/al1NWmclzio)

[7] Quantifying the ocean's biological pump and its carbon cycle impacts on global scales. Siegel DA et al, Jan 2023 (https://www.annualreviews.org/content/journals/10.1146/annurev-marine-040722-115226). Figure 1 illustrates the three pathways of the biological pump, with timescales.
100 billion metric tons of carbon = 1 gigatonne (GtC) = 1 petagram (PgC).

[8] Carbon reservoir ocean: how the sea absorbs carbon dioxide, 2023 fact sheet (https://cdrmare.de/wp-content/uploads/2023/06/CDRmare24_en_carboncy_factsheet_230606V2.pdf). See also: The ocean carbon cycle. DeVries T, Jul 2022 (https://www.annualreviews.org/content/journals/10.1146/annurev-environ-120920-111307) – more technical.

[9] The immeasurable value of plankton to humanity. M Grigoratou et al, Jun 2025 (https://academic.oup.com/bioscience/advance-article/doi/10.1093/biosci/biaf049/8172382). Phyto-plankton are photosynthesizing plant plankton; zooplankton eat other organisms for energy and nutrients.

[10] Researchers parse the future of plankton in an ever-warmer world. N Jones, Oct 2024 (https://e360.yale.edu/features/plankton-climate-change)

[11] Harmful algal blooms: NOAA state of the science fact sheet, Mar 2025 (https://coastalscience.noaa.gov/news/hab-noaa-fact-sheet/). Severe algal blooms hit South Australia and west North American coasts this summer (https://www.climate.gov/news-features/event-tracker/record-breaking-algal-bloom-expands-across-north-pacific, Sep 2025) and (https://www.abc.net.au/news/2025-07-23/sa-toxic-algal-bloom-explained/105560008, Jul 2025).

NOTE: My next write-up will be delayed due to an upcoming vacation. Best wishes to all, Shirley