ALBERT CALBET

The Wonders of Marine Plankton

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To all those who recognize the preciousness and beauty of the ocean and its inhabitants, and who believe in their preservation and protection.

Introduction

I would lie if I said that I have always been passionate about the sea. As a child, I experienced the motion sickness caused by boats, which was far from pleasant for my stomach. However, it is true that since my childhood, I have been fascinated by aquatic microorganisms and living beings in general. I suppose everything changed for me on December 31, 1976 (the day I turned 8), when my parents gave me a toy microscope. That simple plastic device with low optical quality determined my destiny.

I still remember my first unicellular organisms, collected from water in a sun-exposed flower vase. The tiny ciliates and green algae that filled my retina left an everlasting mark on me. That day, I decided I would become a biologist and study microorganisms. As the years passed, fueled by that idea, I used my first paycheck to buy a new microscope, to which I attached a rudimentary camera. Then another one, almost professional, with which I took numerous microphotographs. I began my studies in Biology and continued pursuing my passion; no puddle, reservoir, or container of putrefying water could resist my curiosity. Gradually, I started my own cultures of protozoa and algae, improving my photographic technique to the point of participating in a photography exhibition at the Faculty of Biology in Barcelona. It was those photographs that caught the attention of some teachers and paved the way for me to receive a scholarship to carry out a doctoral thesis on marine zooplankton at the

Institute of Marine Sciences, CSIC, under the supervision of Professor Miquel Alcaraz. And that is where it all began.

After three decades dedicated to the study of marine plankton, I believe the time has come to share my knowledge of this fascinating world, a privilege that only a few of us have had. While it is true that most people are aware of jellyfish, which can prove bothersome during summer, and have heard about the detrimental impact of plastic pollution in our seas, the warming of our oceans, and the acidification that harms coral colonies worldwide, there is still much more to comprehend. Few individuals truly grasp the significance of plankton in our lives, their amazing beauty and intricate complexity, and, most importantly, the urgent imperative to conserve them. Perhaps a handful may recognize terms such as protists, phytoplankton or have come across images of zooplankton in a scientific exhibition or outreach publication. However, widespread awareness and appreciation of the vital role of plankton remain insufficient.

In this book, I will attempt to provide a scientific yet clear understanding of what plankton are and the various functions they perform. I will introduce you to creatures that may be unfamiliar, but could easily appear in fantastic or even terrifying novels, and discuss processes that occur in the sea every day, unnoticed by most. In short, I will delve into everything that is not typically seen when looking at the sea and what lies hidden within a mere droplet of water. Throughout, I will strive to present this information in an engaging and entertaining manner, while maintaining scientific rigor.

The book begins with some general chapters on the functioning of the marine planktonic food web, followed by details about specific groups, and curious aspects of plankton, and ends with a few chapters about plankton study and discovery. You can read this book from start to finish (which I recommend) or choose random chapters, although I suggest starting with at least Chap. 1.

Contents

About the Author

Albert Calbet is a marine researcher working at the Institute of Marine Sciences, CSIC (Barcelona, Spain), specialized in the ecology and eco-physiology of micro- and mesozooplankton. He has made significant contributions to the field, particularly in understanding the role of micro-zooplankton in marine food webs. Albert completed his Ph.D. in Marine Sciences in 1997 at the Institute of Marine Sciences (ICM), CSIC, after which he pursued postdoctoral research at the University of Hawaii at Manoa. He has held various positions at ICM, including Deputy Director. Albert has published over 120 peer-reviewed articles, authored books, and book chapters and actively participated in scientific conferences worldwide. He has been involved in teaching and mentoring students at the Ph.D., Master, and undergraduate levels. Albert's research has been supported by prestigious institutions, and he has served as a reviewer for funding agencies and on the editorial boards of scientific journals. Committed to science outreach, he manages several Web pages and engages with the public through social media, outreach articles, and books.

1

A Teaspoon of Seawater: A Tiny Ecosystem

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The ocean's smallest inhabitants, plankton, drive vital processes. Phytoplankton, microscopic plant-like organisms, produce oxygen and fuel marine food webs. Bacteria break down organic matter, while viruses control microbial populations. Zooplankton, including copepods, support ecosystems by feeding on phytoplankton and transferring energy to higher trophic levels. This intricate web sustains life and nutrient cycling, showcasing the ocean's efficiency and balance.

During my college years, when studying ecology, I recall an interesting exam question: How many whales inhabit the Mediterranean? To solve the problem, we were provided data on primary production (phytoplankton output) and the average weight of a whale. Using a model of energy transfer through the trophic web, assuming 10% efficiency at each trophic level, the calculation itself was straightforward. The real challenge was determining the number of trophic steps to consider. At that time, when we were all naively confident, believing things unfolded exactly as described in textbooks, we settled for a trophic network model with two, maybe three, steps between algae and whales. However, after devoting more than 30 years to studying marine planktonic food webs, I now realize I would likely fail that exam. The problem lies in the fact that nature is far more intricate than we could ever anticipate, and generalizations are often arduous, if not impossible.

Typically, the smallest organisms are not only the most abundant but also play vital roles. This holds for plankton, which, though mostly invisible to the naked eye, are crucial to marine trophic food webs. Planktonic organisms sustain life on Earth, generating half of the oxygen produced on the planet and forming the basis of the nourishment of the fish we consume. Unfortunately, they also originated fossil fuels like oil. What can we do? After all, nobody is perfect.

Before digging into the story of plankton, let's introduce the primary characters. Imagine a teaspoon of seawater, approximately five milliliters, that you could collect at the beach. Within this small volume, we would find around 50 million viruses, five million bacteria, several hundred thousand photosynthetic or heterotrophic flagellates (unicellular organisms with whip-like appendages), thousands of microscopic algae, a handful of heterotrophic ciliates or dinoflagellates, and if we are lucky, one or two small crustaceans, such as copepods. The plant component of plankton is referred to as phytoplankton, whereas the animal component is known as zooplankton. Although the term zooplankton encompasses both unicellular and multicellular organisms, we typically distinguish them by size. Hence, we have microzooplankton (mostly unicellular and very small) and mesozooplankton (multicellular, or proper animals).

Each member of the plankton community serves a specific function. Viruses (which do not affect humans) regulate the populations of bacteria and other microorganisms to prevent excessive proliferation. Bacteria,[1] in turn, decompose organic matter and aid in nutrient recycling. Without them, corpses and waste would accumulate to unimaginable levels; considering the length of time we have inhabited this planet, if not for the activity of bacteria, we would likely be walking or even climbing upon a sea of corpses. Bacteria carry out intricate reactions that break down organic matter into inorganic compounds (salts of nitrogen, phosphorous, etc.), which can then be utilized by the primary producers—phytoplankton. Additionally, bacteria contribute to the cycling of various chemical elements, such as sulfur and iron.

Phytoplankton (marine unicellular vegetables; Fig. 1.1) are responsible for assimilating the inorganic salts generated by bacterial activity (particularly nitrates, phosphates, and silicates) and incorporating them into living matter. Through the process of photosynthesis, they also capture CO_2 (+ H_2O) and convert it into organic matter with the assistance of solar energy. During this photosynthetic process, phytoplankton release oxygen—a by-product that has the unfortunate tendency to oxidize objects but is essential for our existence. Concerning oxygen, it is frequently mentioned on outreach websites, in the press, and even in some scientific publications that marine algae contribute to roughly half of the oxygen we breathe. Although this statement may hold on a geological timescale spanning millions of years, it is not accurate on a daily basis. It is correct that phytoplankton have contributed to accumulating over half of the oxygen in the Earth's atmosphere throughout the history of the planet, and without their photosynthetic activity, animal life as we know

[1] Actually, the correct term should be prokaryotes, which encompass bacteria and archaea. However, for the sake of clarity I will use the term bacteria.

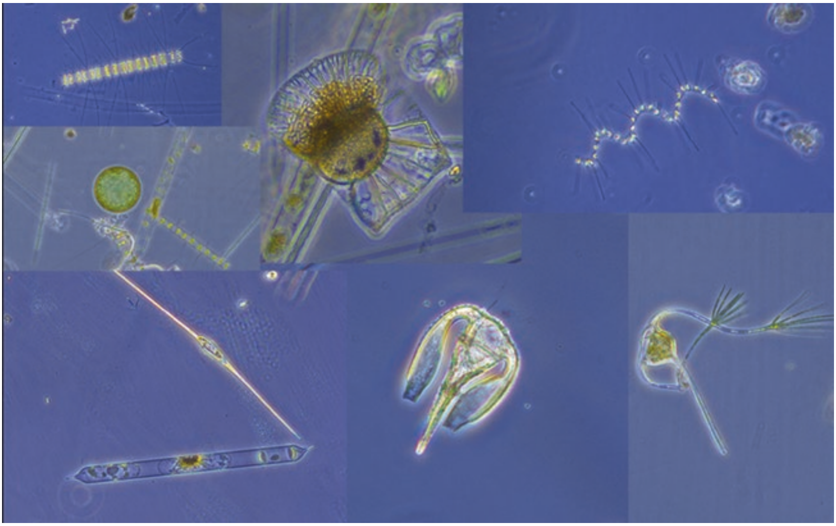

Fig. 1.1 Different microalgae from the phytoplankton. © Albert Calbet

it would not have colonized the Earth's surface. It is also true that phytoplankton, with only about 1% of the biomass of terrestrial plants, account for approximately 50% of photosynthesis and is responsible for roughly half of the daily oxygen production on the planet. However, the majority of this oxygen produced in seas and oceans is consumed by the various micro- and macro-organisms that reside there, and only a minute fraction reaches the atmosphere.

Consumers of phytoplankton can range from unicellular organisms like flagellates, ciliates (Fig. 1.2), dinoflagellates, or foraminifera, to multicellular ones, such as worm and mollusk larvae, starfish, fish larvae, crustaceans, and jellyfish. Among the multicellular organisms, copepods (Fig. 1.3), a group of crustaceans usually measuring no much more than a millimeter, are the most abundant animals on the planet—surpassing even insects. Copepods serve as the primary food source for fish (and occasionally whales, although they prefer larger prey like krill). However, before reaching this stage in the food web, copepods must feed on ciliates, algae, and other microscopic organisms.