Ilaria Perissi
Ugo Bardi

THE EMPTY SEA

The Future of the Blue Economy

A Report to the Club of Rome

Springer

The Empty Sea

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ISBN 978-3-030-51897-4 ISBN 978-3-030-51898-1 (eBook)
https://doi.org/10.1007/978-3-030-51898-1

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Ilaria dedicates this book (her first) to her daughter Viola, who was 7 years old while we were writing it, with the hope that the sea will remain clean, beautiful, and full of fish, whales, dolphins, and all the rest when she will grow up.
Ugo dedicates this book to the sperm whale Giovanni, with the hope that he can swim free and happy for many years in his sea, the International Cetacean Sanctuary in the Tyrrhenian Sea.

Foreword by the Co-presidents of the Club of Rome

It is with great pleasure that we present this new report to the Club of Rome. *The Empty Sea* is the latest important publication of a long series of seminal reports that started in 1972 with the well-known study titled *The Limits to Growth*. The present report is dedicated to the future of the marine economy, often called "The Blue Economy." It is a joint work by two experts in the field of natural resources: Ugo Bardi is a full member of the Club of Rome, well known for his studies on resource depletion, while Ilaria Perissi is a relatively new but exciting entrant in this field due to her innovative studies on the overexploitation of marine resources and on climate change mitigation.

The Empty Sea complements previous studies sponsored by the Club of Rome by applying a "systemic" approach to ensure that we understand the importance of the marine economy as an integral part of our natural ecosystem. It is a view that *The Limits to Growth* introduced in 1972 as a major innovation in economics that up to then (and, unfortunately, still now) tended to see the ecosystem just as an "externality" resulting in the underestimation of its importance. *The Empty Sea* gives us the first innovative research effort to successfully apply the dynamic models used in *The Limits to Growth* to the marine economy. This book could rightly be seen as a continuation of that early study and we could call it "The Limits to Growth of the Oceans."

The results presented in this book are especially relevant given the current scramble to exploit the sea as the "Blue Economy." This over-zealous, unmitigated frenzy on the exploitation of the sea is raising too many expectations and creating a rampant "blue acceleration." The sea is now seen as the new frontier that will provide humankind with abundant new resources of food, minerals, and energy.

It is not the intention of the authors to underplay the importance of these resources for humankind as they clearly show us that the sea does indeed contain vast resources, in many cases much less exploited than those on land. But it does invite all of us to seriously reflect on a fundamental truth: all resources, no matter how abundant in the beginning, are subjected to overexploitation. It doesn't matter if a resource is renewable or non-renewable. In most cases, overexploitation means losing it forever. We know that many of today's fish stocks have been destroyed by

overfishing and in several cases reported in the book they have not had the time to properly regenerate and perhaps never will.

The Empty Sea provides a deep word of warning to the world: "We probably can, if we want, transform the blue and rich sea into a stinking brown puddle." And, if the exploitation of the seas continues at the present rate, that is the risk we face. The key question this book addresses is the reason of our compulsive need as humans to destroy the resources that give us life. The answer lies in our tendency to continue to think using an obsolete paradigm that sees continued economic growth as the ultimate solution to all problems and always a good thing. But growth is obtained not only at the expense of the ecosystem, but also at the expense of poor people of the world, who are exploited, mistreated, and discriminated against. They are the first to experience the disastrous effects of ecosystem destruction.

We need a change of paradigm to return to seeing harmony and social justice as the way to manage our society instead of competition and profit, which is the dominant current view. Only in this way can we create a sustainable and resilient society, able to develop effective emergency plans and long-term systems shifts to effectively emerge out of our self-imposed planetary emergency, working collaboratively to promote well-being for people and planet.

This book fits perfectly into the tradition of the Club's reports. It is **NOT** an academic tome destined for the bookshelves, but rather a well-informed perspective on the importance of the marine environment to human survival, and is engagingly written with the view that it should be read and understood by many. It contains plenty of historical notes, interludes on various aspects of the human interaction with the sea, including ancient art, literature, and myths. This is captured by the image of the two authors dressed as Captain Ahab and as Moby Dick, the whale, playing the drama of whale hunting in a theatrical performance.

We hope you will enjoy this rich publication as one more offering of the Club of Rome to challenge all of us to become better stewards of our planet. This is another reminder of our responsibility as humankind to protect the endowments that our biosphere has so generously gifted us, and ensure that ecosystems are properly protected and preserved now to assure we "emerge from the emergency" and leave a healthy planet for generations yet to be born.

March 2020

Sandrine Dixon-Décleve
Mamphela Ramphele

Foreword by Daniel Pauly

There are many books that document how intensive and uncontrolled fishing leads to overexploitation of fish resources and impoverishment of the biodiversity of the oceans. In the process, overfishing leads to the fisheries themselves disappearing, a sad but entirely avoidable outcome.

These books – and I confess to having written a few, and also contributed to those of many other authors – are usually boring as they are aimed at experts in the world of fisheries research, which means that in order to read them, you must be interested in fisheries in the first place.

The Empty Sea was written by two established scientists who, however, are not fisheries specialists. Thus, this book presents the problem of uncontrolled fishing from a different perspective, a perspective foreign to that of the experts. I hasten to add, however, that this outsider perspective makes their book better than the typical fishery tome, because any reader, whether or not interested in fishing, can benefit from it.

In fact, *The Empty Sea* does what none of its competitors do: it aims at the reader who cannot be reached by specialists, mainly by documenting the intellectual dimensions of fishing and fishers. In other words, considering that fishing is historically one of our two main interactions with the ocean (the other is maritime transport). It shows that it is worth reflecting deeply on the role that fishing has in our history, economy, and everyday life.

The authors show that, since ancient times, the impact fishing has on the oceans is one of the most frequently treated themes among nature writers. The authors also introduce concepts pertinent to the technical language of fishing (maximum sustainable yield, total allowable catch, and other important indicators) but contextualize them in a whimsical and entertaining way, both from a historical and an intellectual point of view, through examples and quotes ranging from Peter Paul Rubens (the painter) to John Steinbeck (he of Cannery Row), from the great mathematician Vito Volterra to Captain Iglo, and from the Neanderthals to El Niño, happily jumping, in the process, from the humanities to the sciences and vice versa.

The theme of fishing lends itself particularly to a dynamic narrative of this sort, since a wide range of disciplines are evoked when studying, for example, the

interactions between biological entities (such as fish) and hand-made tools (for example bags for gathering, and spears for hunting). Because of its dynamic narrative, a book like this cannot be boring and, in fact, it is not. Without losing the reader, the authors manage to retrace much of the history of fishing and, at the same time, to introduce the main concepts of fisheries science.

The authors also deal with the impact that global warming is having on fish and the slow-motion disaster caused by the enormous amount of plastic that is suffocating the seas. Both of these issues are belated confirmations of the existence of "Limits to Growth," that is, of limits to economic growth, as already highlighted in the 1970s in a study of the same name by the scientists of the Club of Rome.

Vancouver Daniel Pauly
February 2020

Preface

Those who study the sea do so in many ways and from different angles. There are oceanographers, biologists, fishery scientists, geologists, economists, and many more. And then, of course, there are fishermen, poets, singers, writers, painters, and all those who simply enjoy the sea, including the vacationers who take to the beaches in summer.

The authors of this book do not fall into any of these categories, except marginally. We are both from a research field called "biophysical economics," part of the larger domain of physical chemistry that our common teacher, Professor Enzo Ferroni, called "the science of all interesting things." It is a science that ranges from atoms to ecosystems while attempting to explain all phenomena in terms of the basic laws of physics. Biophysical economics is part of this approach, being a branch of the science of complex systems, truly the most interesting field we have found in our careers.

We started by studying mineral resources, but then we found that the fishing industry provides another example of how human beings do not know how to manage what makes them live. In this field, we followed a path already traced by the great mathematician Vito Volterra (1860–1940), who found himself studying fishing in the Adriatic almost by accident (his daughter had married a marine biologist). We do not know whether he realized that with his equations – developed in parallel by Alfred Lotka in the United States – he was starting a new field of science known today as "System Dynamics." We hope that Professor Volterra, from where he is now, in the Elysian fields, may watch us and be pleased by the work we have been doing, inspired by his!

Our approach was fruitful. We worked on the equations developed a century ago by Lotka and Volterra to study fishing and that later on were the basis for the model used for the "*The Limits to Growth*" study of 1972. We found that similar models could also describe modern fishing; it was the first time that these models were applied in this field. From there, we went on exploring this fascinating world, the sea, its creatures, how humans are expanding in a new realm, and appropriating for themselves what they see as "resources."

The results of these studies were a series of fascinating discoveries. The most worrying one is that we are really emptying the sea. That's right. Do you remember the old Chinese story that goes "give a man a fish and he will eat for a day. Teach him to fish and he will eat for a lifetime"? It is a wise story if referred to fishing in ancient times when it was a craft that did not damage marine resources. Today, we should modify it as something like, "give a man a fish and he will eat for a day, teach him how to fish and he will empty the sea." That's exactly what is happening and, if the current trends continue, the trend will accelerate. This is the story we tell in this book. It is not only a story about the sea, but also one of how we humans relate to the resources that sustain us and often succeed in destroying them in our continuous search for profit.

In the end, this book was born from the desire to tell a story, the great story of humans and the sea, from the Paleolithic to what we can call today "the war against the sea." And here we tell you this story the best we can, trying to make this subject understandable for everyone, especially to young people who could find themselves living in a world where fish are only a memory and where jellyfish snacks have become an everyday event.

Firenze, Italy

Ilaria Perissi
Ugo Bardi

Acknowledgments

We would like to thank the people who helped or inspired us in this work: Sabina Airoldi, Stefano Armenia, Toufic El Asmar, Marina Clauser, Valeria D'Ambrosio, Stefano Dominici, Sara Falsini, Valeria Fenudi, Charlie Hall, Alessandro Lavacchi, Miguel Martinez, Gianluca Martelloni, Alexandra Morton, Salvatore Tredici, and the Tethys Research Institute. We thank Dave Packer for having made this book possible. Special thanks are reserved to Daniel Pauly, much more expert than us in all matters related to the sea, who helped us a lot and corrected many of our mistakes in the initial draft of this book. We thank also Tatiana Yugay of the Moscow State University who kindly agreed to write for us something about the history of the Sturgeon fishery in the Soviet Union and in Russia, her contribution is part of this book. We also thank Anna Ricca for the publication of the Italian version of this book by "Editori Riuniti" in 2020 with the title *Il Mare Svuotato*. And, finally, we thank our families who supported us during the writing work.

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Ilaria Perissi has a Ph.D. in physical chemistry (2009). She is engaged in research on biophysical economics and climate change mitigation at the University of Florence. Dr. Perissi is a member of the scientific board of the European Federation "Transport & Environment" and the author of various articles on the use of systems dynamics models in the study of the exploitation of resources, particularly in fishing. She writes on these subjects on her blog "*Boundaries*" at https://ilariaperissi.blogspot.com/

Ugo Bardi teaches physical chemistry in the School of Natural Sciences at the University of Florence. He is a member of the Club of Rome and author of many studies and books dedicated to resource exploitation. Ugo Bardi is also editor of the journal *Biophysical Economics and Sustainability* (Springer). He writes about sustainability and the environment on his blog "Cassandra's Legacy." (www.cassandralegacy.blogspot.com). His latest book is titled *Before the Collapse* (Springer 2019).

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Chapter 1
Introduction

If you ever were stung by a jellyfish while swimming in the sea, you know how painful it is. To be accurate, we should say that jellyfish do not sting, but instead their tentacles emit noxious or "urticating substances" on contact. Nevertheless, they are beautiful creatures, and if you ever saw a group of them swimming in their tank in an aquarium, you know that you could stay there for hours admiring their ethereal qualities and unique form of locomotion (Fig. 1.1).

But, no matter how beautiful and fascinating these creatures may be, a brief contact with one of them is more than enough to ruin your holiday. The abundance of jellyfish in the sea is one of those gradual changes that over time has become the "new normal," a bit like the increasingly intense and frequent heat waves in summer. Young people swimming at the beach today organize anti-jellyfish squads that watch the waters so that their friends can swim in peace. But those of us who are a little older can remember how, long ago, the jellyfish problem just did not exist. Surely, there were plenty of poisonous jellyfish in the sea, but they were rare enough that no one was preoccupied with the risk of being stung.

Perhaps you have also had the opportunity to swim at some distance from the beach. In this case, you may have noticed something else. Where have the fish gone? Apart from a few small fish near the beach, there seem to be no swimming creatures in the sea except the human ones. Again, that looks normal to us, but if you think that once upon a time the coasts were inhabited everywhere not by tourists but by fishermen, then you must conclude that there is something strange going on. If the sea had always been the way you see it now, what could the fishermen catch with their small boats, certainly unable to go very far? Did they fish for jellyfish? Or how did they make a living? They are mostly gone now. Certainly, there are still fishing boats in the world, plenty of them, but no longer the romantic kind of boats of the past. Now fishing is an industrial activity done with fast boats equipped with all sorts of fancy tools, from radars to sonars. Sometimes, they look more like spaceships than fishing boats. What happened to the sea?

Obviously, the occasional observations we can make while swimming near the beach are no proof of anything. But many things have indeed changed in the sea in

I. Perissi, U. Bardi, *The Empty Sea*,
https://doi.org/10.1007/978-3-030-51898-1_1

Fig. 1.1 Jellyfish kept at the Berlin aquarium. In the foreground, one of the authors (UB)

recent times and not just with fishing. For one thing, the data show that jellyfish and other invertebrates have become much more common today than they were just a few decades ago. Lobsters were once a fancy and expensive food that few people could afford, but, today, they have become common enough to begin to appear, frozen, in supermarkets and even not especially fancy restaurants have them on the menu. In certain regions of the world, in particular in China and Japan, even jellyfish are becoming a fairly common food. Not that they are very nutritious or particularly tasty: they are made mainly of water. But it is said that they are acceptable after being dried and sprinkled with some spicy sauce. In this case, they are crunchy, a little like cucumbers. In the West, jellyfish are not normally considered as food, but things change fast. How about a jellyfish pizza? Why not a jelly burger?

It is also true that overfishing has caused the disappearance of many fish species, especially those that were easy to catch near the coast. It is what Daniel Pauly called "aquacalypse" in a study that he published in 2009 [1], one of the first reports on the destruction of the marine environment by human activities. Not that all fish have disappeared, but the populations of the most prized fish, from tuna to salmon, have been shrinking in all the seas of the world. So, there are fewer fishermen and they

catch less and less because there is always less fish. But for most of us, nothing seems to have changed in the availability of fish. At the supermarket, you can still buy as much fish as you want at reasonable prices. If overfishing is a problem, how come consumers have not noticed it?

Indeed, overfishing is not visible if you try to detect it from what you can see available on supermarket shelves. But the fish you buy today is not anymore the fish of a few decades ago. Most of it is farmed fish, bred and raised in an artificial environment, the product of a new industry called *aquaculture* that maintains the shelves of the retail stores well stocked with the most prized fish. The success of aquaculture has led to a complete reorganization of traditional fishing. Instead of producing fish for human consumption, fishing is now oriented mostly on the production of fish to be used as feed for aquaculture. It is a revolution that causes fishing boats to go fishing for species that once nobody could have imagined as being food for human beings. Have you ever been served sand eel or capelin at a restaurant? Unlikely, but these are species actively searched by the fishing industry as sources of feeds for more valuable species, such as salmon. But the race to the bottom goes on. It was unthinkable a few years ago that the fishing industry would engage in exploiting the tiny shrimp called "krill," once just whale food, but today another source of protein for fish feeds. Curiously, though, krill is also considered as a food for humans, and you can order fried krill in Japan by asking for *okyami.* Some people seem to be seriously thinking of plankton as food for humans. Do you want to know what it tastes like? It is reported that it tastes "fishy" [2]. Are you surprised?

Now you begin to understand. Fish eat jellyfish and, if fish disappear, jellyfish thrive and you are more likely to be stung. It is all part of a gigantic change occurring everywhere in the seas of the world. It is not only about fish and fishing; the sea itself is changing. It is becoming more acidic because of the absorption of increasing quantities of carbon dioxide from the atmosphere. It is becoming polluted with all sorts of chemicals, from metals to pesticides, including the plastic waste that is forming the great "plastic islands" in the oceans. And the sea level is also rising because of two parallel effects, both related to global warming. First, the rising temperature of the water causes it to expand. Then the melting of the continental ice adds water to the oceans. So far, these effects have been small enough to be difficult to notice without appropriate instrumentation, but, in the future, pollution and sea level rise will cause tremendous damage to humankind.

Sometimes, we hear that there exist no problems, only opportunities, and some people seem to be applying this concept to the changes taking place in Earth's oceans. This mind-set underlies the concept of the *blue economy*, and its close relatives *blue growth* and *blue acceleration*. These terms encompass all of the activities that justify our exploitation of marine resources. In addition to fishing, the sea is also exploited for its mineral resources: the drilling platforms that you see offshore to extract oil and gas are a good example. Think also of desalination plants, nowadays more and more widespread to fight the droughts caused by global warming and to supply water to thirsty humans. These plants produce huge amounts of drinking water, but there is always a cost as large quantities of energy are required to move the water away from the salt and against the osmotic pressure. And then there are

many other activities based on the sea: transportation, tourism, military operations, scientific research, and many others. The sea is no longer the romantic lair of brave and noble fishermen. It is an arena for industrial development. It is an economic resource.

Of course today there is no more talk of the wild ideas that were fashionable in the science fiction novels of the 1950s, such as submarine cities. But we talk about many other things that were not even imaginable before our times, referring to the treasures that are believed to be contained in the sea. It is said that the blue economy will bring us a new era of prosperity, and not just that, it will be "sustainable prosperity." This idea has become so popular that it is also used to define technologies unrelated to the sea as long as they are sustainable, as described in the book *The Blue Economy* by Gunter Pauli (2009). But the popularity of the blue economy is, more than anything else, the result of a specific factor: the spectacular development of aquaculture. Once, aquaculture was a small-scale activity, mostly done in China to produce shrimp and other seafood for supplementing the family diet. But, today, aquaculture produces almost as much as traditional fishing and generates a much larger turnover at hundreds of billions of dollars per year globally. It is one of the few industrial sectors that you can still expect to grow dependably every year and sometimes at double-digit rates. This growth has led to seeing the blue economy as a great success of human intelligence and resourcefulness. Our march toward the conquest of the sea is proceeding smoothly toward ever more amazing successes. We will get everything we need from the sea: food, energy, minerals, even cosmetics, and do not forget the expansion of tourism and trade routes. It's the blue economy, baby! But can we really have our cake and eat it, too?