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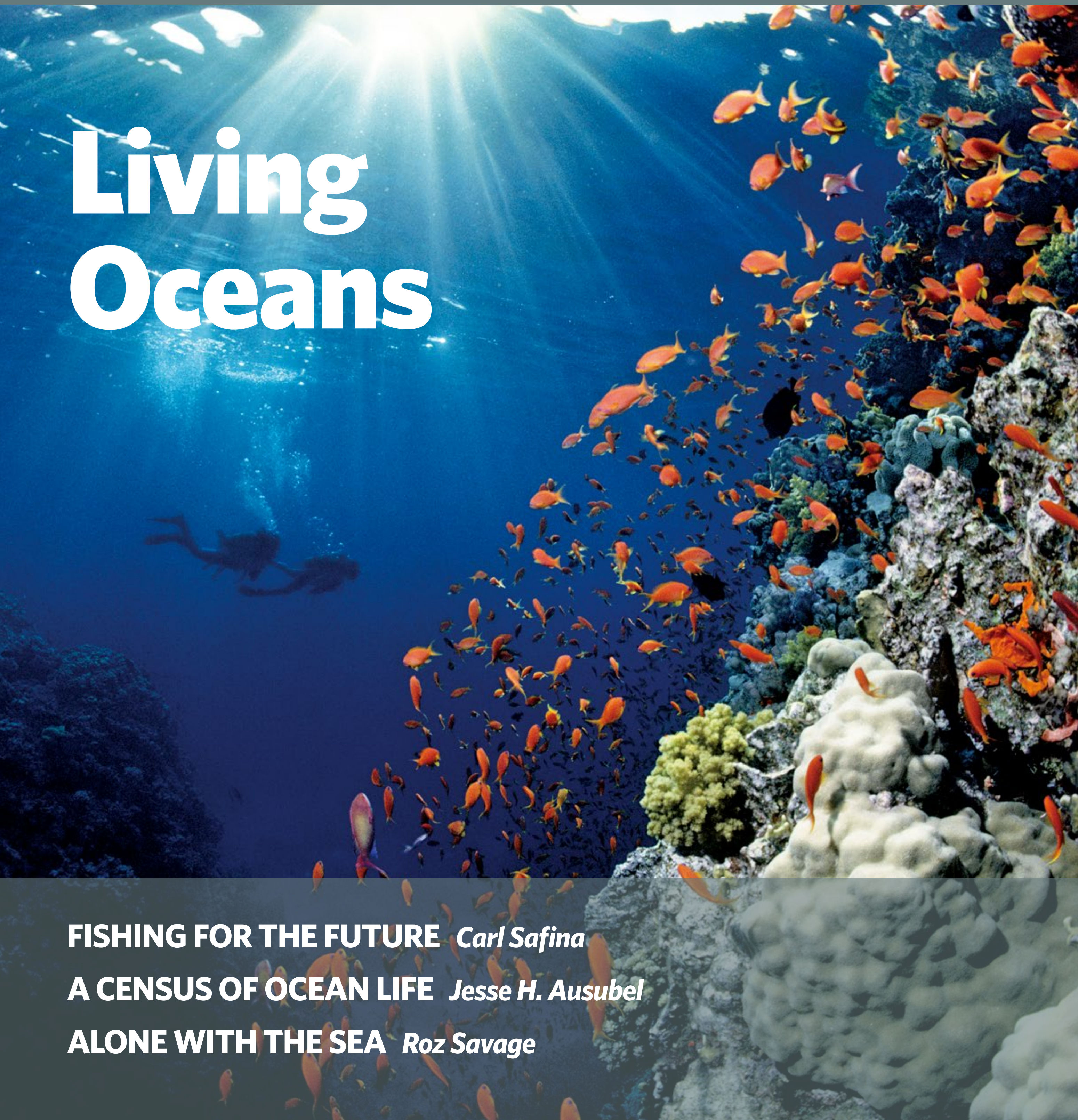

Living Oceans

FISHING FOR THE FUTURE *Carl Safina*

A CENSUS OF OCEAN LIFE *Jesse H. Ausubel*

ALONE WITH THE SEA *Roz Savage*

A Census of Ocean Life:
On the Difficulty and Joy of Seeing What Is Near and Far

By Jesse H. Ausubel

The Census has counted more than 17,000 species in the frigid, sunless ocean depths below 1,000 meters, a region long viewed as devoid of life.
Top left: A tiny copepod from 5,000 meters below
Main photo: At 2,750 meters an odd transparent sea cucumber, *Enypniastes*, creeps forward on its many tentacles at about 2 cm per minute while sweeping detritus-rich sediment into its mouth
Bottom left: "New" Dumbo octopod, *Grimpoteuthis sp.*

In the late 1990s, leading marine scientists shared their concerns that humanity's understanding of what lives in the oceans lagged far behind our desire and need to know. Some emphasized the question, "What lives?" in its most elementary form. They pointed to the opportunity for discoveries about the diversity of life in the vast global ocean. For example, ichthyologists (marine scientists who study fish) identified about 15,000 marine fish species but believed about 5,000 more awaited discovery. The age of exploration in the oceans was by no means over.

Others asked, "What lives where?" They highlighted establishing a baseline of known occurrences of marine life and then plotted a strategy for drawing reliable maps of likely distributions.

Still others asked, "How much of each lives?" They pointed to the changing abundance of species and the need for improved management based on a sound foundation of knowledge. They warned of exploitation of continental slopes and sea mounts and pointed to contentious debates about the abundance of even supposedly well-known cod, tuna and salmon species.

Happily, the diverse scientists converged on a strategy, a worldwide Census to assess and explain the diversity, distribution and abundance of marine life. The founders organized the Census of Marine

Above: *Chiasmodon niger*, the great swallower; it can capture and ingest prey that is bigger than itself and has a huge stomach

Life around three grand questions: What did live in the oceans? What does live in the oceans? What will live in the oceans?

They agreed to report in the year 2010 what humanity knows about the oceans, what we do not yet know but could learn, and what will still be very hard to learn or is even unknowable.

The founders of the Census recognized that comparing past marine life with the present would provide a running start on projections. "What did live in the oceans?"—the first question—motivated a Census program called the History of Marine Animal Populations, which paints pictures of what lived in the oceans before humanity's fishing became important, a time stretching back thousands of years in some cases and 50 in others. From these pictures, analysts can dissect the influence of fishing, habitat loss and climate variability on marine life populations.

In addition to this, the key components of the Census are 14 field projects to investigate, "What does live in the oceans?" The projects span near-shore to open ocean, surface to abyss, equator to pole, and microbes to mammals. Building on the history program and the 14 field projects, the Census also developed a program to answer, "What will live in the oceans?"

Above: A "Jurassic" shrimp, *Laurentaeglyphea neocaledonica* from the Coral Sea, believed to have gone extinct 50 million years ago

The integrating element is a database called the Ocean Biogeographical Information System (OBIS) that collects and makes Census information widely and durably accessible. The Census has already archived more than 20 million records on more than 120,000 species in OBIS, which links to other powerful databases that provide genetic descriptions of species and biographies of them in an Encyclopedia of Life (*www.eol.org*).

Limits of Knowledge

It helps to understand what you know and why you know it, what you do not know but might readily learn, and what is hard to learn or might even be unknowable. That is, it helps to understand the limits of knowledge. Knowing what you do not know, like writing *terra incognita* on a map as Roman geographers used to do, can help as much as adding detail to lands you have already explored.

In considering ocean life, the causes that separate the known, unknown and unknowable are numerous and diverse, falling into five families: the invisibility of the lost past, the vast expanse of the oceans, difficulties of assembling parts into a whole, blinders we put on ourselves, and surprises from outside.

The first family of limits is the invisibility of the lost past. Some phenomena leave no traces or may have left traces we cannot find. In New York City, many are shocked and disbelieving that reefs of oysters extending for hectares dotted New York Harbor 200 years ago. Even if the animals may be lost

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in the past, their oil, bone, dyes, fur and DNA may survive intact or in records. Still, we need imagination to explore the limits of our knowledge of the past.

It is also difficult to see what is far, dark, deep or under pressure (the second family of limits). Expanse also challenges the timeliness and frequency of observations. Only a few governments regularly send vessels or divers out to assess stocks directly. Ships trawl only in a few locations, their sonars probe only narrow swaths where vessel noise or pressure waves may scare away fish.

Because light can penetrate to a shallow seafloor, the near-shore may seem easier to study than deeper realms. But even here, the vastness of even the ocean edges—the variety, rarity and patchiness—creates limits to knowledge.

The third family of limits, assembling parts into whole models, encompasses statistical challenges. Fisheries and biodiversity statistics are inadequate. Fishers tend to underreport catches, and commerce addresses fished stocks, rather than fish stocks. Whether a species is truly absent, or present and uncounted, bedevils much biodiversity data. Even counted species may be misidentified. Mathematical models used to turn available data into assessments of stocks or abundance may misbehave. Small

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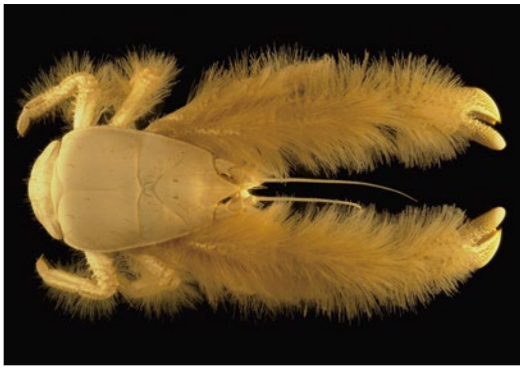

mis-specifications in initial conditions magnify into tornadoes of error.

The fourth limit is the blinders we put on ourselves, which stem from both economics and culture. The agencies that survey stocks, such as environmental or fisheries ministries, are poor and obtain only small or brief samples. They concentrate on commercial and charismatic species in convenient or attractive locations and seasons. Blinded by disciplinary myopia, experts overlook species or numbers. We act as if the 1 or 2 percent of the 250,000 named species of marine life that enter commerce have an independent identity. Although microbes make up 90 percent of ocean biomass, researchers have largely ignored them, too.

We bring cultural biases that lead us to exclude or discount certain data and information. What is near may seem so familiar that we take it for granted. Often we know only what an oil company or local government pays for.

"Census researchers in the Gulf of Maine project watched 50 million herring swimming in a school almost the size of Manhattan."

A tsunami exemplifies surprise interventions from outside, the fifth family limiting knowledge. Surprising events can harshly limit our knowledge. Abrupt changes disturb our orderly world.

Discoveries

Limits may discourage us, but overcoming limits brings victory. The Census of Marine Life pushes at the extremes marking the boundaries of knowledge. Four extremes exemplify the discoveries of the Census.

Hottest: At the site of a seafloor vent in the extreme pressure three kilometers beneath the equatorial Atlantic, Census researchers encountered water at a broiling 407 degrees C. Nevertheless, in heat that could easily melt lead, life continued! Although the overheated species resembled those around cooler vents, differences in chemistry show how life adapts in a furnace.

Richest: The richest biodiversity discovered was 20,000 kinds of bacteria that the Census found floating in a liter of seawater near a fissure erupting 1,500 meters deep on a seamount in the Northeast Pacific. DNA sequences taken by the Census revealed that most of the 20,000 kinds were unknown and certainly rare. This richness invites speculation about what rare species contribute to their biosphere and invites an estimate that there are at least 20 million kinds of bacteria in the oceans.

Farthest: Tags attached by the Census to sooty shearwater birds and continuously monitored by satellite mapped a small bird's search for food back and forth across the Pacific Ocean, from Chile to Japan to California and New Zealand in a giant figure of eight. This 70,000-km journey—350 km a day for 200 days—is the longest trip of any animal ever recorded.

Most: Census researchers in the Gulf of Maine project watched 50 million herring swimming in a school almost the size of Manhattan. A new technology of focused sound scanned areas a million times wider than ever before. The scan reveals the swelling and shrinking, fragmentation and merging of the schools as a person might watch schools of minnows swimming in a brook.

The discoveries were made by 2,000 Census scientists from 80 countries. The shearwater flying 70,000 kilometers did not carry a passport. I hope that someday everyone who cares about the ocean carries a Census of Marine Life passport, exemplifying humanity's systematic challenge to the limits of knowledge and devotion to conservation of ocean life. Together, we can see clearly the marvels of what is both near and far, propelling the world to preserve and increase life. ❖

Above left: South of Easter Island, Census vent explorers discovered a crab so unusual it warranted a whole new family designation, *Kiwaidae*. Beyond adding a new family to the wealth of known biodiversity, its discovery added a new genus, *Kiwa*, named for the mythological Polynesian goddess of shellfish. Its furry or hairy appearance justified its species name, *Hirsuta*

Above right: At 2,000 to 2,500 meters, a bizarre, elongated orange animal identified as *Neocyema*, only the 5th specimen ever caught

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Photo credits: (top left) Ifremer/A. Fifis; *(top right)* David Shale