



Alasdair D. McIntyre

The many Census scientists who contributed to this volume dedicate it to the memory of Alasdair McIntyre, who passed away near its completion. Some of us knew him for many years, while others for only a few, but we all greatly appreciated his wisdom, wit, and perpetual curiosity. His contributions to marine science have been many and he was one of the first to propose an international study of marine biodiversity. Alasdair will be greatly missed.

Foreword

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The Census of Marine Life is about the total richness of the sea:

The Census of Marine Life is the book of oceans' nature. This book reports total richness.

It reports richness of diversity, the richness of what.

It is about kinorhynchs, tardigrades, rotifers, gastrotrichs, and tantulocarids housed in Arctic polynyas.

It is about Antarctic actiniarians, pycnogonids, tunicates, and holothurians.

It is about the golden V kelp in the Aleutian Islands.

It is about polychaetes, bivalves, and isopods of the continental margins.

It is about sturgeon and salmon, sea turtles and pinnipeds, otters and sirenias.

It is about filter feeders.

It is about radiolaria and hydrozoa.

It is about lanternfishes and pearlfishes and roundnose grenadiers.

It is about a black, benthopelagic lobate ctenophore and a large pelagic worm with ten long cephalic tentacles.

It is about 10,000 crabs.

It is about 5,000 to 19,000 unique types of bacteria in each gram of sand.

It is about Upper Turonian diatoms.

This is a book about vastness and deepness.

It reports richness of distributions, the richness of where.

It is about the Western and Eastern Pacific, and about South American seas.

It is about Caribbean, European, and Polar seas and Indian and Atlantic oceans.

It is about the abyssal plains and basins beneath half of Earth's surface.

It is about the Porcupine Abyssal Plain.

It is about the canyons of the margins.

It is about large shallow banks and gravelly shorelines.

It is about Lizard Island and Ningaloo Reef.

It is about the architecture of seamounts.

This is a book of journeys.

It is about leatherback turtles tagged on their nesting beaches in Indonesia crossing Pacific longitudes to feed off central California.

It is about sooty shearwaters flying Pacific latitudes from New Zealand to the Bering Sea.

It is about water columns 5,000 meters high.

It is about the planet's busiest commute, the nightly rise of life from hundreds of meters deep to feed nearer the surface in the safety of darkness.

It is about circumpolar currents.

This is a book that explores abundance, the richness of how much.

It is about the northerly flowing Kuroshio Current along the southern Japanese coast characterized by high biodiversity but low biomass.

It is about shimmering shoals of herring swirling in numbers beyond counting.

This is a book about past richness.

It is about Greek merchants trading fish from the Black Sea and the Russian rivers to the Greek and later the Roman market.

It is about the decline of marbled rock cod and mackerel ice fish west of the Antarctic Peninsula.

This is a book of lost reefs.

This is a book about life and death.

It is about juvenile salmon and adult sturgeon.

It is about immature specimens carrying sperm packages.

It is about the loneliness of reproductive isolation.

It is about mass mortality.

It is about small dead coral heads.

It is about prey fields patrolled by marine hunters.

It is about fidelity to birthplace.

This is a book of paradoxes, where extreme is normal and rare is common.

This is a book of contrasts.

It is about the cosmopolitan and the local.

It is about glaciation and boiling seafloor geysers where metal would melt yet animals live.

It is about ancient assemblages and modern benthos.

It is about swimmers and drifters and sitters.

This is a book of mysteries.

It is about oceanic barriers to gene flow.

It is about trophic subsidies to carnivores.
It is about the immense volume of ocean still unexplored.
It is about 20 million marine microbes that might remain
to be described.
It is about cryptic species.
It is a book of powerful prostheses.
It is a book of ships and sledges and gliders and
pyrotags.
It is a book of attached identity cards and different mesh
sizes.
It is a book that filters a million cubic meters of seawater.

It is a book of blue-water divers.
It is a book where yellow dots are actual observations of
lionfish.

This book reports the known, unknown, and unknowable
of the first Census of Marine Life.
This book is about the richness of 3.5 billion years.

Jesse H. Ausubel
Alfred P. Sloan Foundation

Introduction

INTRODUCTION

Reflecting upon the successes of the Census of Marine Life over the past decade, I am recalling how my contemporaries and I first became interested in marine biodiversity. As an undergraduate, I had a small National Science Foundation grant to study the macrofaunal invertebrates in samples taken to examine sediment transport processes either side of a sand–mud transition at the edge of the Labrador Current off what is now the Cape Cod National Seashore. The leader of the expedition, John Zeigler, wanted to know how wave activity controlled sediment transport and the location of the transition from sandy to muddy sediments on the seafloor, and Howard Sanders wanted to know what lived either side of this transition. Except for the specimens from Vineyard Sound described by the great naturalist A.E. Verrill, most of the organisms belonged to undescribed species. Subsequently, in graduate school at Duke University, this experience led me to study bottom life either side of another sand–mud transition on the continental slope off North Carolina and, subsequently, to a career identifying and describing the diversity of life on continental shelves and coral reefs and in the deep sea.

In the 1980s, concern about loss of species diversity in all environments greatly increased with the realization that diversity of life in rain forests and coral reefs must be protected and studied. E.O. Wilson and Peter Raven were and still are articulate advocates for maintaining the diversity of life on the planet. In parallel with the efforts to protect terrestrial biodiversity, marine scientists met under the auspices of the International Association for Biological Oceanography and the UNESCO Working Group on High Diversity Marine Ecosystems. Participants at the meetings included leading marine biologists, such as Bruno Battaglia (Italy), Pierre Lasserre (France), Ramon Margalef (Spain), Alasdair McIntyre (UK), Tim Parsons (Canada), and Howard Sanders (USA). In 1990 Pierre Lasserre, Alasdair McIntyre, Carleton Ray (USA), and I wrote “A Proposal for an International Programme of Research: Marine Biodiversity and Ecosystem Function” (Grassle *et al.* 1991). When *Diversitas*, the international program of biodiversity science, was established in 1991, this marine program was incorporated (Ray & Grassle 1991). US support for marine biodiversity began with the establishment of the National Research Council’s Committee on Biological Diversity in Marine Systems, chaired by Cheryl Ann Butman (now Zimmer) and James Carlton. Following a workshop attended by 54

leading US marine scientists, Butman and Carlton wrote *Understanding Marine Biodiversity: A Research Agenda for the Nation* (Committee on Biological Diversity in Marine Systems 1995), one of the most widely read reports published by the National Academy Press. However, this did not lead immediately to a program of research. Colleagues in Woods Hole urged me to talk with Jesse Ausubel at the Rockefeller University, who, unknown to me at the time, was also a program manager at the Alfred P. Sloan Foundation. Starting with initial discussions of the feasibility of a Census of the Fishes, Jesse built strong support within the marine biology community for a broader research approach, and I became the first chair of the Census of Marine Life Steering Committee.

With strong initial commitment, and sustaining support from the Alfred P. Sloan Foundation, this initiative will achieve its goal of a comprehensive Census of Marine Life by the end of 2010. Research on species diversity started with Evelyn Hutchinson’s question in 1959: “Why are there so many kinds of animals?” (Hutchinson 1959). Hutchinson estimated there might be about 1 million species globally and, of these, three-quarters were insects. At that time, ocean life was very poorly known and only a very small proportion of species were thought to live in the ocean. Now, with nearly a decade of support from the Census, a rich diversity of previously unknown marine species has been discovered and previously unknown habitats are being described. The deep-sea floor is no longer considered a desert, characterized by a paltry diversity of species.

Marine scientists are at present unable to provide good estimates of the total number of species in any of the three domains of life that flourish in the ocean (Archaea, Bacteria, and Eukarya). From their molecular signatures, animals are in a relatively well-defined supergroup that also includes the fungi. There are at least five and probably more supergroups. If we consider only the kingdom Animalia, the number of species may be knowable, but it will probably take at least another decade of the Census before we can defensibly estimate the total number of marine species.

Before the Census, most marine biologists studying life in the ocean worked chiefly in shallow water or on continental shelves, where the prime scientific interest was food chains leading to harvestable populations of fish or

shellfish. To achieve an estimate of the diversity, distribution, and abundance of life in the ocean in 10 years, the Census has endeavored to sample the full range of marine taxa from pole to pole and surface to abyssal depths. The products of the Census in 2010 constitute a quantum leap toward a full assessment of life in the oceans, and others are already planning for the second Census in the next decade. It is hard to recall how little we knew just 10 years ago and to predict how much we will learn in the next decade.

To provide the context for studying present-day life in the ocean, the History of Marine Animal Populations (HMAP) project of the Census has asked what lived in the ocean? Changes in the abundance and size of harvested marine populations are being documented from many sources, including records of fish catches, sales and shipping records, writings, photographs, and even restaurant menus. The Future of Marine Animal Populations (FMAP) project recognizes that predictions about future marine life depend on knowing what is being lost from unprotected marine habitats and the rates of recovery following their greater protection.

To learn about the many species in the present ocean, the Census drew together 14 teams of scientists specializing in diverse geographic environments or subject areas:

Coastal areas: Natural Geography in Shore Areas (NaGISA), Census of Coral Reef Ecosystems (CReefs), Gulf of Maine Area (GoMA), and Pacific Ocean Shelf Tracking (POST).

Deep-sea floor: Continental Margin Ecosystems on a Worldwide Scale (COMARGE) and Census of Diversity of Abyssal Marine Life (CeDAMar).

Central waters: Census of Marine Zooplankton (CMarZ) and Tagging of Pacific Predators (TOPP).

Deep-sea floor and Central waters: Patterns and Processes of the Ecosystems of the Northern Mid-Atlantic (MAR-ECO), Global Census of Marine Life on Seamounts (CenSeam), and Biogeography of Deep-Water Chemosynthetic Ecosystems (ChEss).

Polar regions: Arctic Ocean Diversity (ArcOD) and Census of Antarctic Marine Life (CAML).

Microbial life: International Census of Marine Microbes (ICoMM).

The Census has exceeded expectations and lived up to the goals set in the 1995 report, *Understanding Marine Biodiversity: A Research Agenda for the Nation*. The Census has enlisted oceanographers, ecologists, statisticians, and marine biologists to conduct research on a global array of topics:

- Ocean-scale distribution and abundance of marine species using the latest in oceanographic technologies and taxonomic expertise.
- Causes and consequences of changes in marine biological diversity.
- Tracks of individual marine species in estuaries, coastwide, and oceanwide settings.
- Effects of human activities on life in the ocean.
- Previously intractable, oceanwide biodiversity patterns, processes, and consequences.
- Predictions regarding future effects of human activities on marine biodiversity to facilitate use of the sea for societal needs while minimizing impacts on nature.
- Development of partnerships between ecology and taxonomy.
- Reinvigoration of the field of marine taxonomy and systematics, developing the Ocean Biogeographic Information System (www.iobis.org), and collaborating on the World Register of Marine Species (www.marinespecies.org).

The Census has discovered many new species and previously unknown habitats, especially in the deep sea and on coral reefs. Many of the species are rare and most are represented only by single individuals in samples. The new Census datasets are, or will soon be, maintained in the Ocean Biogeographic Information System (OBIS). At the time of this writing, OBIS contains more than 22 million distribution records representing more than 100,000 species.

The Census brings together many things I have wanted to see happen for marine biodiversity throughout my career in marine science, involving more focused scientific effort and better communication to the world of why marine biodiversity matters. This book represents the distillation of the labors of many people who have fostered my original idea to put marine biodiversity in the foreground of the scientific landscape. The Census has been developed and nurtured by fellow architects Jesse Ausubel and the other inspired members of the Scientific Steering Committee now chaired by Ian Poiner (see list on page xix), who guided the project leaders and were the builders who so aptly constructed all of the projects, through the many skilled scientific workers who actually did all of the complex work. The International Secretariat at the Consortium for Ocean Leadership, including senior scientists Ron O'Dor and Patricia Miloslavich and program managers Cynthia Decker, in the early years, and Kristen Yarincik, have been instrumental for the Census. We have had spectacular success with public outreach through the Education and Outreach Team, led by Sara Hickox, and the many contributions of Darlene Trew Crist are especially noted. The Mapping and Visualization Team, led by Pat Halpin, has created a wide range of wonderful and insightful illustrations for many Census projects. And the Synthesis Group,

led by Paul Snelgrove and managed by Michele DuRand, has helped to bring together the many activities in the Census so that the sum is even greater than its many wonderful parts. My longtime friend and colleague Alasdair McIntyre, who passed away as this book was nearing completion, worked with the project leaders and authors of these chapters to distill the efforts of thousands of superb scientists into a single volume that will provide an excellent resource for scientists interested in marine biodiversity.

This volume is one of a suite of products of the first decadal Census of Marine Life. Census researchers have documented their new vision of life in the ocean in more than 2,500 scientific papers and about 30 books so far. There are many products for a variety of audiences. For those interested in what was learned about life in the global ocean from a national and regional perspective, I direct you to the online *PLoS ONE* collection of papers “Marine Biodiversity and Biogeography – Regional Comparisons of Global Issues”. A book by my former student Paul Snelgrove, *Discoveries of the Census of Marine Life: Making Ocean Life Count*, details the Census findings and explains the implications of what has been learned for both a scientific and interested public audience. A richly illustrated narrative, *World Ocean Census*, written by Census colleagues Darlene Trew Crist, Gail Scowcroft, and James M. Harding, Jr, introduces the work of the Census to the

public. Lastly, there is a delightful photographic guide to marine life written by Census colleague Nancy Knowlton, *Citizens of the Sea: Wondrous Creatures from the Census of Marine Life*. Separately and collectively, these documents serve as a tribute to the hard work, dedication, and true scientific achievements of the more than 2,600 scientists from more than 80 nations who accomplished this novel and important scientific endeavor known as the Census of Marine Life.

Fred Grassle
April 2010

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Alasdair D. McIntyre

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