Foreword

Future Knowledge of Life in Oceans Past

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An English prelude

I am always comfortable and happy among historians because my father, whom I liked very much, was a historian. He specialized in 19th-century Britain. Every few years, my father would bring the family by transatlantic passenger liner from New York City to Southampton for a long stay to conduct his research. I crossed the North Atlantic by ship 12 times, a rare privilege for someone born in the middle of the 20th century. Since the 1960s, aviation has separated travellers from the power and mystery of the oceans.

Like all visitors to England, my family marvelled at cathedrals and castles. Unlike most visitors of the 1950s and 1960s, we also marvelled at the cities that manufactured, and were manufactured by, the industrial revolution. My family lived in Manchester for a year, when coal smoke still fogged that city. We visited nearby Rochdale, where streams and canals riveted textile mills and whose weavers struck for cheaper grain imports in 1843. We climbed the seven hills of Sheffield, carved by the six rivers that were harnessed to power the wheels that sharpened the famous Sheffield steel.

Like many boys, I became fascinated by railroads and maps. I still have some of the maps of Britain I collected. One series compares Britain before and after the Industrial Revolution. Before the industrialization process set off on its dynamic, remorseless course, large green areas on the maps housed fewer than 12 inhabitants per square kilometre. In my mind, this was the world of castles, of the tales of King Arthur and Robin Hood, of forests and deer, of silk and leather.

Industrialization inevitably shrank these green and pleasant vistas, as networks of canals and railways, and clusters of factories and 'dark satanic mills' proliferated and altered the landscape. This was the world of novelist Charles Dickens and Oliver Twist, of brick and steam, of cities and coal. I found the industrial landscape fascinating – no less fantastic a stage for the imagination than undisturbed woodlands. And the industrial landscape reached from Britain around the world, conveyed in Kipling's 'great steamers white and gold', and Masefield's 'dirty British coasters'. Cotton came from plants sunning in Egypt and India, wool from sheep grazing in Australia, whole grain and flour from the wheat belt advancing westward across the US, while mundane, but vital, cargoes – timber from the Baltic, dairy produce from Denmark, fruit from the Mediterranean – came overseas from nearby Europe. Outwards from the workshop of the world went the money, the people and the 'Tyne coal, road-rail, pig-lead, firewood, iron-ware and cheap tin trays' that helped to spread the 'industrial spirit' across the globe.

The English landscape proved that the history of nature is, or became, the history of *human* nature. The History of Marine Animal Populations (HMAP) research programme of the Census of Marine Life (CoML) is demonstrating how the seascape, like the English landscape, has both influenced and been cultured by the courage, ingenuity and folly of human endeavour.

An orientation to the Census of Marine Life

During the late 1990s, several leading marine scientists shared their concerns with the Alfred P. Sloan Foundation that humanity's understanding of what lives in the oceans lagged far behind our desire and need to know. Some of the scientists emphasized the chance for exciting discoveries about the world in which we live. Much remains to be discovered about the diversity of life in the oceans. For example, ichthyologists have so far identified about 16,000 species of marine fishes. They also believe that about 4000 species of marine fishes remain to be discovered and described. The age of exploration in the oceans is not over. Other researchers highlighted the importance of establishing baseline information on the distribution of marine life. For most marine animals, we lack reliable maps of their range or distribution. Pointing to the changing abundance of many species, other researchers called for improved management of fisheries and marine reserves. They noted increasing exploitation of largely unsurveyed areas, such as the continental slope and sea mounts, as well as violent debates about numbers of supposedly well-known species, such as cod, tuna and salmon.

Happily, these diverse scientists converged on a strategy to address their concerns: conduct a worldwide census whose purpose would be to assess and explain the diversity, distribution and abundance of marine life. The founders of the programme organized the Census of Marine Life (www.coml.org) around three grand questions:

1 What lived in the oceans?
2 What lives in the oceans?
3 What will live in the oceans?

Implicit in this outline research agenda is the recognition that a survey of contemporary marine life would have much more value if compared with historical information. Accordingly, the first grand question – what lived in the oceans? – motivated the HMAP programme that has created this book.

Commencing in 2000, CoML is a decade-long programme that will conclude with the First Census of Marine Life in 2010. While the 2000 or so researchers participating around the world are now three-quarters of the way through the ten-year period, the census will reach its highest peaks during the next couple of years in terms of effort and output, since all the components of the census work towards the 2010 synthesis. Alongside HMAP there are three other key elements of CoML:

1 It has 14 field projects, which are all making new observations in diverse realms to reveal much about 'what lives in the oceans'.
2 The question of 'what will live in the oceans' is addressed by the Future of Marine Animal Populations (FMAP) programme.
3 CoML's data assimilation framework, the Ocean Biogeographic Information System (OBIS) provides both archiving and access with regard to research results.

Opportunities for synergy between HMAP and the rest of CoML abound. HMAP researchers are already integrated with some of the ocean realm field projects – for example, in the Gulf of Maine area – and I wonder whether they might further enhance their cooperation with scientists surveying today to present a seamless past and present for that exemplary region, which has been exploited for almost 400 years. Both of the polar regions provide scope for integrating past and present. I wonder whether HMAP's walrus and seabird experts might link with CoML's Arctic team, and with researchers engaged in the circum-Antarctic Census of Marine Life, to document not just two or three but many decades of populations of albatross, of which 19 of 21 species are now endangered. Mention of walruses and birds leads to the global question of whether HMAP experts on top predators, including whales, seals and turtles, might join with the Tagging of Pacific Predators (TOPP) field project to create knowledge that spans long periods and wide oceans for these long-lived and far-ranging animals.

Links already exist between HMAP and FMAP. The former's millennial studies of the Wadden Sea have adapted analytic tools of the kind that ecologists have developed for prediction, while FMAP researchers have exploited more than 50 years of data on catches of long-line fishermen to learn and forecast trends in the diversity, distribution and abundance of tuna and billfish. Forecasting and back

casting are two sides of the same coin, and researchers in HMAP and FMAP are sure to find mutual benefit by sharing data and tools.

HMAP is already a major provider of data to OBIS, which in 2007 had already facilitated access to about 13 million records of 80,000 species, and aims to provide tens of millions of records for more than 200,000 species. The extrapolation and digitization of historical data uncovered in archives located across the globe will be one of HMAP's great legacies. The integration of this material within larger databases will allow us to perceive patterns over larger areas, longer eras and covering more forms of life. OBIS interacts with historians by presenting the fruits of their research in new, innovative ways, and also by adapting its framework to accommodate data that were generated for various purposes, in many different forms, by an array of agencies that functioned long ago. Drawing on OBIS, everyone involved in the census can devise enthralling new visualizations. In an era when all information is born digital, CoML has the chance not only to perform analyses and create insights in words and numbers, but to share them in both static and dynamic images. Long appreciative of the power of maps, historians have much to contribute in making CoML innovative in the forms with which we share what we learn.

LIMITS TO KNOWLEDGE

I strongly believe that it helps to understand what is known and why we know what we know, what we do not know but might readily learn, and what it is very hard to learn or might be unknowable. In other words, it helps to understand the limits of knowledge. In the census we often refer to these limits by speaking of the known, the unknown and the unknowable. For both producers and consumers of knowledge, knowing what you do not know, like writing '*terra incognita*' on a map, can be as valuable as adding detail to lands that you have explored. Disclosing the limits to knowledge can also be among the most useful of acts. Such disclosure helps people to choose where to explore, avoid frustration and hedge bets.

The limits that separate knowledge into the known, unknown and unknowable are numerous and diverse. Like biodiversity, these limits call for taxonomy. Let me offer a taxonomy of limits to knowledge divided into five families:

1 The vastness of the present state.
2 Reasoning from the parts to the whole.
3 Surprise interventions from outside.
4 Blinders we put on ourselves.
5 The invisibility of the lost past.

The first family of limits, the vastness of the present state, encompasses the physical and practical barriers that are integral to ocean space. It is very hard to see what

is far or dark or deep or at high pressure. A fundamental reason that knowledge of marine life remains crude is the imperviousness of water to light. The expanse of the ocean also challenges the timeliness and frequency of observations. Only a few governments regularly send out research vessels to make direct scientific measurements for assessments of stocks. While these ships use trawl nets with constraints upon their mesh size, they also trawl in only a few locations. Their sonar probes only narrow swathes that fish might avoid because of vessel noise or pressure waves. The survey vessels sample a tiny fraction of the sea, mostly near shore and at shallow depths. Technology offers stunning progress in observing marine life; but an ocean observing system that regularly reports a quite complete picture to us is many decades away.

Reasoning from the parts to the whole (the second family of limits) encompasses both statistical challenges and models. There are, and always have been, serious problems associated with fisheries statistics. Fishers tend to under-report catches, and commercial activity addresses *fished* stocks, rather than *fish* stocks. 'By-catch' data are used to fill in estimates of some other species, but also suffer biases. In turn, little is known about the validity of the mathematical models used to transform available data into assessments of stocks. For many species, the sparse knowledge of life cycles may limit the realism of models. Models themselves suffer limits of many kinds, including simplification, while mathematical forms are used, and errors occur in describing initial conditions. Few models capture extremely sensitive, non-linear systems where, for example, an ecological regime shifts from dominance of one species to another.

A tsunami exemplifies surprise interventions from outside, the third of the families. Shocks initiated by humans also belong to this group of limits. A prohibition against fishing would be a surprise intervention by people, as surprising to fish as the shock inflicted on Earth by a tsunami. Yet, as the history of human societies and natural history both testify, abrupt changes do, from time to time, disturb a seemingly orderly world.

The fourth limit (the blinders we put on ourselves) stems from economic as well as cultural factors. Limited funding is made available to the agencies that carry out stock surveys, such as the US National Oceanic and Atmospheric Administration, resulting in small or short samples. Governments in most countries have inadequate means to verify or rectify the numbers that they receive. Disciplinary myopia also causes experts to overlook data. Although microbial life might make up 90 per cent of ocean biomass by weight, researchers have largely ignored it until recently. We also all bring cultural biases to our work, which leads to the exclusion or discounting of certain data and information types. Often, we only know what someone else is willing to pay for.

A fifth family of limits, especially important for HMAP, is the invisibility of the lost past. Some phenomena leave no traces, or they may have left traces but we cannot find them. It is very difficult to reason backwards to what has disappeared. The tendency of successive generations of scientists to supplant the measuring

points deployed by their predecessors with yardsticks of their own, the so-called 'shifting baseline syndrome', falls into this category of 'lost in the past'.

In essence, I urge researchers to continue confronting limits. By identifying them openly, we have a better chance of overcoming them, or to help other people act wisely when faced with hard and seemingly insurmountable limits to knowledge.

Hypothesis: The great reversal

Let me now return to the environment itself. During the 1980s, I studied long-term trends regarding the use of energy and materials. I learned that their efficiency has improved for as long as records are available. A steady increase in the sparing of these resources per unit of output or service provided is normal. In 1992, curious about agriculture, I asked my esteemed colleague, agronomist Paul Waggoner: 'How much land can 10 billion people spare for nature?' By 1996, I began to hypothesize that humanity had reached an inflection point in development about 1970, when the rate of human population growth peaked, allowing improving efficiency to reverse the expansion of cropland in several nations. Seeing expanding forests in several nations and borrowing a phrase from the demographers of *population transition*, geographers now speak of a *forest transition*. Examples from energy, materials, farming, forestry and water use, too, suggested that a 'Great Reversal' of resource use was occurring in several ways.

During the mid 20th century, humans began to reverse the pattern they had followed for millennia of extending further into nature to meet needs for food and materials. Recognizing this Great Reversal, I and my associates explored the areas in human use for cities, logging and farming. We searched for principles and trends to forecast land use in the late 21st century to accommodate a world of 10 billion people. Offsetting the sprawl of cities, rising yields in farms and forests, and changing tastes can release large amounts of land. For example, even with growing population and cities, the US could still newly spare for nature an area twice the size of Spain in the next century. Cutting of forests peaked in the US in 1906, and the volume of both hardwoods and softwoods standing in the nation's forests has risen steadily since about 1950. In fact, studies of forest biomass for the 1990s in the boreal and temperate region in more than 50 countries show the forests expanding in area and/or volume. Globally, a wise and intelligent humanity could extend the 'Great Reversal' into a 'Great Restoration' of nature on land.

What about in the sea? Is a reversal near, and a restoration in prospect, for fish as it may be for trees? Answering the questions of marine reversal and restoration requires answers to two questions: what *lives* in the oceans and what *lived* in the oceans? Here again we come to HMAP. I suspect that human use of the oceans is 100 years behind our use of the land – that is, the forest transition or Great Reversal in land use may precede and foreshadow a Great Reversal in the utilization

of marine resources. The evidence of HMAP may reveal the long-term course of exploitation, including unwise exploitation, of the oceans. HMAP may give a head start of decades and even centuries in anticipating trends – improving as well as declining. Use of overarching hypotheses, such as the Great Reversal on the land, may help HMAP to navigate its work in the sea.

HMAP: Ingenious evidence and tasks

Speaking of evidence, I want to remark further on the ingenuity of HMAP researchers: congratulations on discovering new sources of evidence, and also on finding new evidence in old sources. Along with menus, HMAP's evidence includes buttons and bones, logbooks and lore, paintings and pavements, isotopes and ice. HMAP researchers keep extending the limits of knowledge by finding new ways of making the past visible. They help us to lift self-imposed blinders on what constitutes useful source material. But more information can still be extrapolated from traditional sources. I like to read early texts of geography and history, and since HMAP was launched I have looked at such sources with fresh, wide eyes. Let me briefly mention some indicative material that might be fruitful to revisit. Starting earliest, I think of Seneca's *Naturales Quaestiones* and his treatises on natural phenomena. Another source might be the chronicles of St Brendan, who, it is believed, was born in 484 AD near Tralee, County Kerry, Ireland, where he died in 577 AD. His *Navigatio*, or wandering, was assembled about 300 years later. Some is pure Celtic fantasy, but to me his description of one region as 'curdled ocean' sounds very much like it could be the Sargasso Sea. A fellow Irishman, Dicuil Hiberniae, wrote *De Mensura Orbis Terrae (On the Measure of the Earth's Globe*) in about 825 AD. It is important for providing the first records of Iceland and the Faeroe Islands, as well as the Orkneys and Shetlands. Maybe Dicuil's work is useful for HMAP.

The medieval Icelandic chronicles, the *Graenlendinga Saga* and also *Eirik's Saga* famously offer the primary written evidence for the Norse landfall in North America. We should look again at their accounts through the lens of HMAP. About the same time as Eirik, the Moroccan geographer and cartographer al-Idrisi wrote a Universal Geography, produced in Sicily in 1153. His *Nuzhat al-Mustaq* describes the seas of the North Atlantic: 'There are animals of such great size that the inhabitants of the islands use their bones and vertebrae in place of wood to build houses. They make hammers, arrows, spears, knives, seats, steps, and in general every sort of thing elsewhere made of wood.' Perhaps HMAP can extract some ideas from al-Idrisi about the distribution and size of Atlantic marine animals 950 years ago.

I hope such fantastical ideas stimulate the imaginations of historians and ecologists. The point is, by surmounting limits to knowledge, we can construct the history of marine animal populations. This brings me to what I see as the

three essential tasks of HMAP. The first is to create pictures of what lived in the oceans before fishing became important. In some places, the time is 50 years ago, 500 in others and 1000 or more in a few. More broadly, we might compose a set of snapshots of marine life, say, in year 1, year 1000, and years 1500, 1600, 1700, 1800, 1850, 1900, 1925 and 1950. Second, HMAP is required to dissect the influence of fishing, climate variability and other factors driving changes in marine animal populations since fishing became important. Nature includes human nature and so must its history. The third task is to create and make accessible long time series on marine animal populations and related factors so that future researchers can study the processes of change in the marine environment more effectively. I hope our legacy of data will show not only a course of exploitation, but the path to a Great Reversal and Great Restoration of marine life.

The work undertaken since 2000 suggests that the HMAP community is growing strong. Its field of enquiry, in which historical marine ecology and maritime history are integrated, is as valid within history as the study of the industrialization of Britain. In fact, it is fundamentally the same. As the exciting research presented in this volume shows, by recognizing and lowering limits to knowledge, we can write an epic history: global, deep and human, with imagination and with profit for nature. *Oceans Past* shows the way forward. By continuing on this path down to the First Census of Marine Life in 2010, HMAP will compile richly documented and beautiful answers to the question: what did live in the oceans?

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