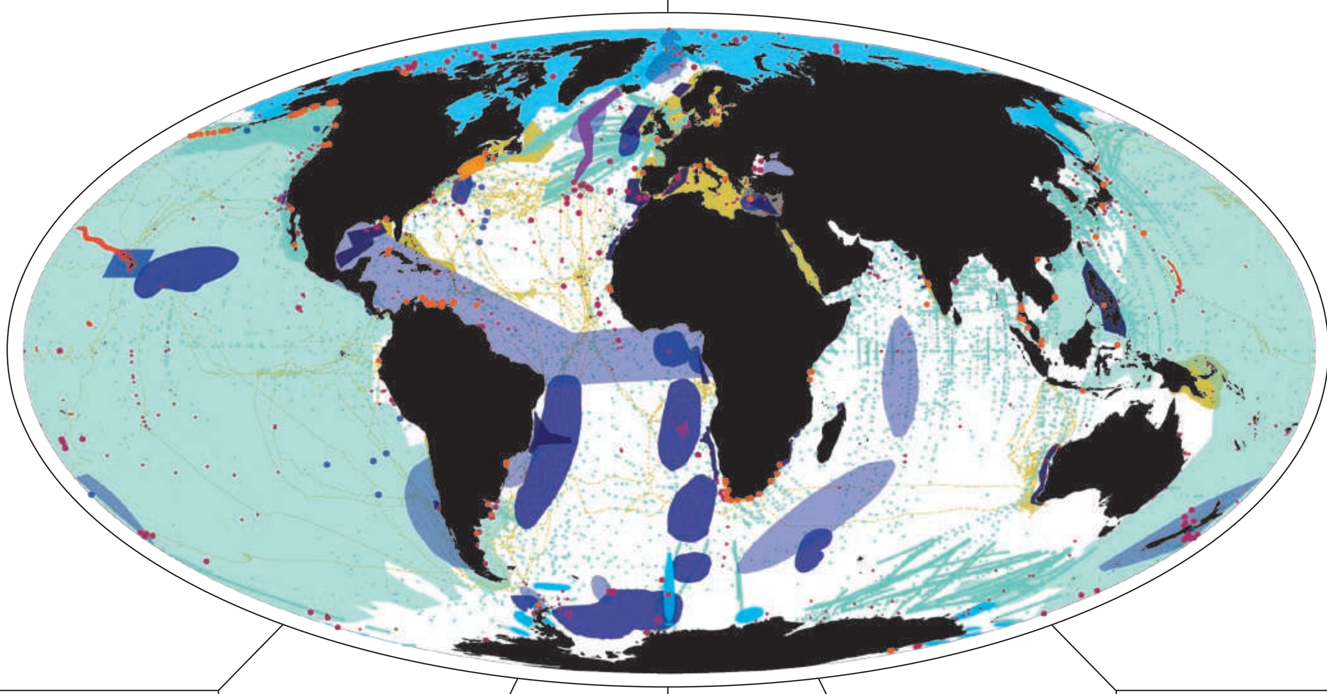
AN OCEANIC INVENTORY

The coloured areas in the map below show the ocean realms studied during the ten-year Census of Marine Life.



COML MAPPING & VISUALIZATION/DONNELLY

OPEN OCEAN Continental shelves; marine zooplankton; birds, whales and other migrating predators.

COASTAL Coral reefs; shallow waters close to shore; regional zones such as the Gulf of Maine.

POLAR The Arctic and Antarctic 'ice oceans'.

DEEP SEA Vents and seeps; abyssal plains; seamounts; continental margins; mid-ocean ridges.

GLOBAL INFORMATION AND ANALYSIS Microbes; oceans past; oceans future; the census information system.

The full, interactive version can be found here: http://comlmaps.org/gallery/footprints

OUT OF THE BLUE

The ten-year Census for Marine Life is about to unveil its final results. But how deep did the $650-million project go?

BY DANIEL CRESSEY

It took just an hour and a half to get the ball rolling, says Jesse Ausubel, thinking back to the day in July 1996 when Frederick Grassle came to his office at the Marine Policy Center of the Woods Hole Oceanographic Institution in Massachusetts.

Grassle, a marine scientist at Rutgers, the State University of New Jersey in New Brunswick, had come armed with a year-old report from the US National Research Council highlighting just how little scientists understood about marine biodiversity. Even well-explored ecosystems such as coral reefs, temperate bays and estuaries contained vast numbers of undiscovered species, to say nothing of the unknown organisms lurking in remote, under-sampled areas such as the polar seas and hydrothermal vents. The report, which Grassle had helped to write, argued that there was an "urgent need" to expand such research, not least because it is so important for fish management and marine conservation.

Ausubel, who is vice-president of programmes for the Alfred P. Sloan Foundation in New York and an adjunct scientist at Woods Hole, was astounded. "I knew that the measurements of life, especially at the species level, were not very good or plentiful," he recalls. "But I learned from him that just the most basic things hadn't been done."

None of the usual government agencies seemed willing or able to tackle the problem, said Grassle, who had been doing his best to talk them into it. But the Sloan Foundation had a mandate to back ambitious projects that had trouble securing funding from traditional sources — which was why Grassle had come to see Ausubel.

"At the end of the conversation, we agreed that we should try to do something big," says Ausubel.

That 'something big' — originally a fairly straightforward survey of marine fish — evolved into perhaps the largest and most expensive programme of marine-biology research ever (see 'An oceanic inventory'). The decade-long Census of Marine Life, which will officially conclude with the announcement of the full census on 4 October, ended up involving scientists from more than 80 countries, in studies not only of fish, but also of organisms such as sea birds, marine mammals, invertebrates and plankton. The scientific goals of the census are as simple as they are ambitious: diversity, distribution and abundance. What lives in the sea? Where does it live? And how much of it is there?

Granted, the project is still a long way from fully answering those questions; a multitude of gaps remains to be filled by future research. And there are doubts about how much of a future there will be: in many countries, marine census projects are still seeking continuing funding.

Nonetheless, the idea that Grassle and Ausubel concocted on that July day in 1996 "has exceeded our wildest dreams", says Ronald O'Dor, a biologist at Dalhousie University in Halifax, Nova Scotia, Canada, echoing a sentiment widely expressed by census participants. Discoveries include a tubeworm that drills for oil in seeps at the bottom of the Gulf of Mexico, and then eats it; the finding that despite the 11,000 kilometres between the polar seas, at least 235 species are found in both; and the existence of a 'brittlestar city', in which tens of millions of starfish-like creatures live arm-tip to arm-tip atop a seamount south of New Zealand.

"The programme has produced, to date, more than 2,500 publications and has made accessible more than 30 million distributional records that are available to everyone," says Ian Poiner, chief executive of the Australian Institute of Marine Science in Townsville, Queensland, and chair of the census's scientific steering committee. "I would doubt we could be criticized for our contribution to science."

With Ausubel's support, the Sloan Foundation eventually put some US$75 million into the census, which formally began in 2000. But that was only a down payment to cover the project's organizational infrastructure — the committees, meetings and interactions between the thousands of scientists worldwide. To fund the research itself, these scientists had to seek out further funding from their respective governments and other sources. The global, ten-year total comes to roughly $650 million.

ALL THE FISH IN THE SEA

The various national efforts were coordinated under 14 census field projects. One example was the Mid-Atlantic Ridge Ecosystem Project, which mapped the organisms living over and around the ridge using everything from manned submersibles and robotic gliders to more traditional fishing equipment such as trawl nets. Another was the Census of Marine Zooplankton, which used techniques ranging from DNA bar-coding to specially developed upwards-scanning sonar to monitor the roughly 6,800 species of plankton.

The census also included projects to understand the history of marine animals, and to model how they would be affected in the future by ecological forces such as fishing and climate change. Most importantly, according to many participants, the census created an Ocean Biogeographic Information System database to hold the millions of records generated by the surveys.

Broadly speaking, says Ausubel, "the greatest advances of the census are in diversity, somewhat less in distribution". When the full roster of results is unveiled next month, those advances will include at least 5,000 new species — many of them strikingly photogenic (see 'Highlights from the deep') — and the publication of many new range maps.

But the results on abundance have been patchy. "Abundance is the hardest," says Ausubel. First the species have to be discovered, then enough observational data have to be collected to create a range map, and then more data are needed on the numbers. Only then can an estimate of biomass be extrapolated.

This incompleteness has fuelled critics of the census, who fault its decentralized organization and the huge number of broad projects that resulted. "Unfocused", is the sceptical summary of Alan Longhurst, a retired marine biologist and author of *Ecological Geography of the Sea*.

Perhaps so, says Paul Snelgrove, an oceanographer at the Memorial University of Newfoundland in St John's, Canada, and chair of the census synthesis group. But without the census, Snelgrove argues, the various national survey projects might have been performed "on a smaller scale and also more in a haphazard fashion" — if at all.

The census was "a bit of a roulette", says Carlo Heip, general director of the Royal Netherlands Institute for Sea Research in Texel and a member of the census's scientific steering committee. "It was not precise planning of what was going to be funded or not." But Heip maintains that there were no major gaps in the census, as the committee made a point of identifying key individuals in the various countries with the power to get proposals financed in priority areas.

Some census participants even hold up its decentralized structure as a model for future big science projects. It does offer practical advantages, says Niki Vermeulen, who researches scientific collaboration in biology at the University of Vienna in Austria, and who studied the census for her book, *Supersizing Science*. She says that large international research projects often falter because of the desire of member countries to fund only their own researchers. "The census structure at least provides a way of solving that issue," she says. "To say, 'Okay, we do the global coordination from separate money, and for the research projects we can still go to the national funding.'"

Looking back on it, says Ausubel, "have we done everything that the public expects a census to do? Probably not." But the creation of the framework is "historic", he says. "That in itself is huge."

"I don't think ten years is the time we should be assessing it," agrees James Sanchirico, who studies marine management at the University of California, Davis. "Maybe it's at 20 years you can look back and say, what has been the impact?" he says, once it has become clear how the data have been used by scientists and decision-makers alike.

Meanwhile, most of the scientists involved in the first census would like to see a second. Without it, the collaborative framework they built in the first decade — which many cite as the census's most valuable achievement — could begin to dissipate. "Unless we find a sugar daddy who is committed to holding these projects together," says O'Dor, "they're going to drift farther and farther apart."

But the Sloan Foundation has always been clear that its funding would not continue beyond ten years. And no other organization has, as yet, agreed to take its place.

Complicating the situation is the fact that there are two very different possibilities for future work in this area, says O'Dor. One is to repeat the census over another ten-year period to monitor how the known populations change. The other is to continue looking for more species. Although O'Dor says he can put a back-of-the-envelope figure of "a few hundred million dollars" on the first option, there is no real limit on the money scientists could spend on the second. "These two jobs are competing with each other," says O'Dor — and the community has yet to agree how to divide the available funding between them.

Grassle, who is on a quest to find support for a repeat census, is undaunted. "Somehow it will happen," he insists. "The rewards are too great to ignore it." ■

Daniel Cressey *is a reporter for* Nature.

HIGHLIGHTS FROM THE DEEP

More than 5,000 species have been discovered since the start of the census. Here are some examples…

Epimeria
An amphipod crustacean; Elephant Island, Antarctica.

Eusirus
A giant amphipod crustacean, nearly 10 centimetres long; Weddell Sea, Antarctica.

Hydatinidae
A gastropod discovered in a sperm-whale carcass; Cape Nomamisaki, Japan.

Chromis abyssus
An intensely blue fish that lives below 120 metres; Caroline Islands, Pacific Ocean.

Cydippid
A ctenophore (comb jelly); Arctic Ocean.

FROM LEFT: C. D'UDEKEM D'ACOZ, RBINS; C. D'UDEKEM D'ACOZ, RBINS; Y. FUJIWARA/JAMSTEC; R. PYLE/BISHOP MUS.; K. RASKOFF, MONTEREY PENIN. COLL.