COLD-WATER CORALS: THE BIOLOGY AND GEOLOGY OF DEEP-SEA CORAL HABITATS

There are more coral species in deep, cold waters than in tropical coral reefs. This broad-ranging treatment is the first to synthesise current understanding of all types of cold-water coral, covering their ecology, biology, palaeontology and geology. Beginning with a history of research in the field, the authors describe the approaches needed to study corals in the deep sea. They consider coral habitats created by stony scleractinian as well as octocoral species. The importance of corals as long-lived geological structures and palaeoclimate archives is discussed, in addition to ways in which they can be conserved. Topic boxes explain unfamiliar concepts, and case studies summarise significant studies, coral habitats or particular conservation measures. Written for professionals and students of marine science, this text is enhanced by an extensive glossary, online resources (www.lophelia.org/coldwatercoralsbook), and a unique collection of colour photographs and illustrations of corals and the habitats they form.

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To our families:

Lea-Anne, Hannah and David Roberts;

Moira, Nessa, Malachy and Penny Wheeler;

Alexander, Christina, Jannik, Jule, Lea and Angela Freiwald;

Peggy, Peter and Jennifer Cairns.

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Preface

Corals are not restricted to shallow-water tropical seas. Of the approximately 5100 coral species alive today over half are found in deep waters. Cold-water corals can be found over a tremendous range of latitudes from tropical to polar regions and from the shallows to the deep sea. We have known about cold-water corals since the mid-eighteenth century, and pioneering oceanographic expeditions in the late nineteenth century frequently recovered cold-water corals in their dredge nets. But only since the 1970s, and particularly in the last ten years, as acoustic survey techniques have improved and been applied to wider areas of the continental shelf, slope, offshore banks and seamounts have we begun to reveal the true extent of cold-water habitats around the world. In this book we try to summarise what we know about cold-water corals and capture the excitement of a field that is now growing exponentially. For instance, a literature search for the terms 'cold-water coral' and 'deep-sea coral' over the 20 years up to 1996 returned less than 300 publications whereas the same search terms for the following 10 years revealed nearly 700 (see Fig. 1).

The scientific community's fascination with cold-water corals has developed for several reasons. As sessile, suspension feeders that produce complex, sometimes long-lasting, three-dimensional structural habitat they fall at a natural confluence of biology, hydrography and geology. A few species of scleractinian cold-water corals develop elaborate reef frameworks that have spawned many studies into the processes underlying cold-water coral reef and coral carbonate mound formation. Individual cold-water corals, notably species of gold (*Gerardia*) and black (antipatharian) corals may live for over a thousand years, making them by some margin the longest-lived animals in the oceans. The skeletal remains of these corals and long-lasting reef and mound deposits now provide unique palaeoceanographic archives of intermediate water mass temperature and age.

This book's focus is on those cold-water corals that form structural habitat. We will consider how these species function as animals by reviewing what we know

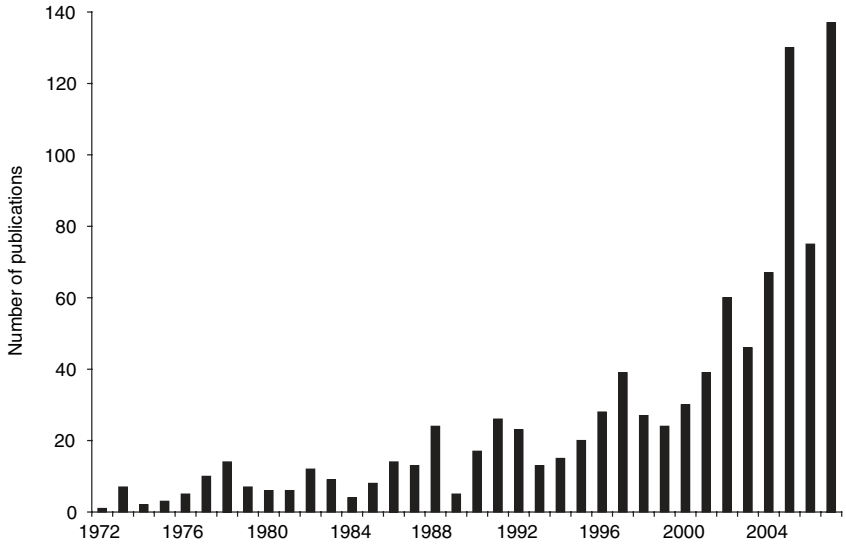

Fig. 1. Histogram showing the number of research papers referring to 'cold-water coral' or 'deep-sea coral' between 1972 and 2007. Special publications devoted to cold-water corals appeared in 2002, 2005 and 2007 explaining the higher number of papers in those years.

of their feeding, growth, reproduction and physiology. In many instances our biological understanding is limited by the practical difficulties of studying any group of animals that live at great depths far from shore. In contrast, our ability to map areas inhabited by cold-water corals is now well advanced and has revealed surprisingly extensive provinces of cold-water coral reefs and huge seabed mounds formed by multiple generations of reef development stacked one upon the other. Long, drilled cores through these coral carbonate mounds are now providing intriguing insights into their geological history and development reaching back over two million years. But corals trace their origins even further back in time and as a group have a chequered history of extinctions and radiations, often in concert with global changes in ocean carbonate chemistry (a critical issue to understand as we enter an era of ocean 'acidification' brought about as anthropogenic carbon dioxide dissolves in the oceans). We consider these long temporal aspects from the fossil record and summarise what we know of cold-water coral palaeontology and the factors underlying preservation of the corals and other animals in the geological record.

Present-day cold-water coral habitats excite interest from all who see them because, like coral habitats in warmer, shallower waters, they are structurally complex and rich with other animal species. Careful surveys with modern submersibles and remotely operated vehicles have brought back stunning images

of cold-water coral habitats that have captured the imagination not just of research scientists but also members of the public and policy makers. Although work is at an early stage, we are beginning to unravel patterns underlying cold-water coral biodiversity. Some coral habitats seem important to fish populations while others may be less significant. We urgently need properly integrated biodiversity studies related back to sound taxonomy to unlock the patterns controlling species diversity in cold-water coral habitats.

However, the same surveys that brought cold-water corals to public attention have all too frequently revealed that they have been damaged by fishing activity, primarily by bottom trawling. Concern over this damage has led to the creation of several marine protected areas to conserve these habitats. At the time of writing, international discussions on high seas conservation had begun and we consider these issues and how conservation policies can be developed and enforced to protect cold-water corals from future damage. But anthropogenic activities in the deep sea are no longer limited to bottom trawling. Deep-seabed mining, for years the stuff of science fiction, is now becoming a reality and with improved subsea technologies and international demand for metals at an all-time high it seems likely to expand by exploiting mineral deposits within seabed hydrothermal vent systems. Overlying all these activities the effects of climate change may dramatically alter the marine environment. As sea temperatures warm and anthropogenic carbon dioxide is absorbed by the oceans we are witnessing a gradual shift to more acidic ocean pH. Corals, along with all calcareous organisms, face an uncertain future. Corals calcifying in deep, cold waters may be among the first to feel the effects of predicted changes in the carbonate saturation state of the seas. Ocean acidification may shift calcareous marine systems from states of growth to dissolution. Warming seawater temperatures may perturb their physiology and food supplies. It seems that we risk dramatically increasing the stresses on cold-water coral habitats just as we begin to understand and appreciate them.

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