is presented. Colin Little and Jack Kitching have managed an appropriate end run around some of these challenges. Their book, as advertised, is strictly on rocky shores. History, evolution, quantitation have been ignored or minimized, making the material relatively accessible to students with little background. Tacit assumptions are that a suitable study site is within reach and that the taxonomic barrier generated by the phyletic richness of rocky shores will be overcome by hands-on examination.

To what extent, then, are the authors successful in conveying their admitted interest in and prejudice toward rocky shores? A superficial answer would be "very." The book is hardly an encyclopedia of fact; it *is* well written and attractively illustrated. Beginning each chapter with a description of what has been learned about particular species or topics in northwest Europe is one way of achieving focus. It also provides a convenient format for developing comparisons with selected rocky shores elsewhere (New England, some shores in western North America, South Africa, and New South Wales), which leads naturally toward the concluding sections on comparative community ecology. The lengthy tradition of experimental manipulation and hypothesis testing which permeates rocky shores ecology is well developed. The questions and research suggestions that conclude each chapter could well challenge and stimulate introductory students.

Since I also have spent much of my career "messing about on a rocky shore" (their preface), why am I reluctant to effusively recommend this book? The answer, I believe, comes from three sources. A trivial one is their creative geography (p. 26, my study of *Pisaster* removal was not in California; p. 59, spread of *Sargassam* from British Columbia to New Mexico would be miraculous), and some minor scientific quibbles. More substantial is my concern that facts lost in the simplification of certain studies are essential for their interpretation. The role of sea otters along the entire shore of western North America is a case in point. Finally, because rocky shores are such attractive places for study, controversies abound and simmer. The authors' allusions to these left me with a feeling of incompleteness, because many are nearer to resolution than admitted. However, and maybe in part because of the above, the book is interesting, creatively illustrated, and peppered with extensive—and almost current—references. Posterity should treat it well if it serves as a model for future texts presenting hypotheses and their tests within focal environments.

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MAZZOCCHI, M. G., G. ZAGAMI, A. IANORA, L. GUGLIELMO, N. CRESCENTI, AND J. HURE. 1995. **Atlas of marine zooplankton. Straits of Magellan: Copepods.** Springer-Verlag, New York. ISBN 0-387-58228-2. 279 p. $99.00.

The subantarctic province is the ice-free circumglobal zone extending northward from the antarctic Polar Frontal Zone to the Subtropical Convergence. Despite considerable attention in recent years to the subpolar oceanic ecosystems of the (northern) subarctic Pacific and subarctic Atlantic, there has been relatively little analysis of pelagic ecosystem processes in the geographically extensive subantarctic. One region where Pacific subantarctic waters meet those of the Atlantic is in the straits between the Patagonian mainland and Tierra del Fuego. Unappreciated by Ferdinand Magellan—and many since—while transiting these straits are the 45 or more species of subantarctic planktonic copepods in these waters. The present monograph describes and illustrates each species, situates them in their local hydrographic circumstances, and comments on their geographic distributions. A companion volume on other pelagic crustaceans and chaetognaths of the region is expected by the time these comments are printed.

The authors point out that many of the original illustrated species descriptions of subantarctic copepods were published in specialized expedition reports and now-rare monographs. In harkening back to the careful illustrations of naturalists of the last century the authors serve a decidedly 21st century cause: the need to clearly establish species' identities, in order to understand rules of assembly and disassembly of ecological assemblages. This rekindling of appreciation for the taxonomic and biogeographic underpinnings of biological oceanography extends well beyond those concerned with marine biological diversity and community ecology. Problems of ecosystem function and biogeochemical cycling also turn on an understanding of the identity and uniqueness of the organisms present. There is a common interest in the support of qualified taxonomists.

The volume includes brief descriptions of the copepods' physical and chemical milieu in the Straits of Magellan, reminding us of the deep basins (to 1,200 m), strong tides at the Atlantic entrance (mean amplitude of 7.8 m), frontal systems, and the major contribution of picoplankton to phototrophic biomass and primary production (in summer). Although useful, this section contains annoying lapses in units (water density as "gamma-t", integrated Chl *a* in "mg/m^2/d," inconsistent usage of units in adjacent paragraphs). The technical quality of the next section is much higher. This—the core of the volume—contains the descriptions of all of the copepod species recognized by the authors. The written descriptions are concise, treating essential characters of both adult females and males. The illustrations are remarkable. They comprise several hundred original line drawings and scanning electron micrographs, including a whole animal habitus for each species and illustrations of many individual characters, often shown from more than one perspective. The stylistic consistency of the drawings facilitates comparisons among taxa. Both the SEMs and rendered drawings were made to a high technical standard. The vertical distribution of most species in different sectors of the straits is also illustrated (and included in tables), although lacking information on the developmental stage composition of the species depicted.

The animals described here were collected on one expedition in late austral summer (February to March 1991) and thus may be expected to include a significant, but not complete fauna of the region. Consultation of other works treating the copepod fauna from different sectors of the subantarctic (Bradford-Grieve 1994 and preceding memoirs in that series; Razouls 1994) reveals a number of differences in the species reported. Some of these differences are geographic and some nomenclatural in origin. The Bradford-Grieve series is to be recommended for those seeking broader geographic and deeper systematic understanding of the species; the Razouls volume treats both the subantarctic and antarctic fauna. The Mazzocchi et al. volume has at least one systematic lapse (dated generic and species designations for members of *Eucalanus*). Reports of several apparently cosmopolitan species based on morphological criteria beg for analysis by the tools of molecular systematics.

Missing from this monograph is any means of identifying copepod species other than by thumbing through the pages. Although such an approach is acceptable to those familiar with the fauna, the lack of a key will frustrate the neophyte. The problem of efficiently identifying unknown species looms even larger in most ocean regions where species diversity is higher. With the development of digital taxonomic expert systems in several laboratories, the present volume would lend itself nicely to conversion to a digital form that includes matrix-entry keys and other pathways for identification. Meanwhile, this splendidly illustrated regional faunistic inventory is worth having—opened—on the laboratory benchtop.

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SUMMERHAYES, C. P., K.-C. EMEIS, M. V. ANGEL, R. L. SMITH, AND B. ZEITZSCHEL [EDS.]. 1995. **Upwelling in the ocean. Modern processes and ancient records.** Environ. Sci. Res. Rep. ES 18. Wiley, New York. ISBN 0-471-96041-1. 422 p. £75.00

Dahlem workshops originated in 1974, as a joint promotion between the Stifverband für die Deutsche Wissenschaft and the Deutsche Forschungsgemeinschaft, to "promote an interdisciplinary exchange of scientific ideas as well as to stimulate cooperation in research among international scientists" (p. ix–x). In contrast to most academic meetings they have no formal presentations, but encourage concentrated discussion within and between groups of invited experts. Under the umbrella of the workshop's main theme, four questions are addressed through background papers written by these experts, the aim being to clarify what is known, illuminate contentious issues (where possible), and suggest possible directions for future research. Each group produces a report of its deliberations, and these reports, together with the background papers (revised according to suggestions received from workshop participants) make up the published conference volume. *Upwelling in the ocean* is the latest in this series.

The goal of the workshop, according to the book's title page, was "To establish the way in which upwelling systems operate as integrated physical, chemical, and biological systems on a variety of time scales from seasonal to geological, and to assess their predictability and response to climate change." An introductory chapter by the editors provides an "executive summary" of the book and a set of recommendations for future work and leads to sections on the four key questions: 1. How do coastal upwelling systems work? 2. How do open ocean upwelling systems work? 3. How do upwelling systems vary through time? and 4. Does upwelling have a significant influence on the global carbon cycle? The corresponding group report follows each section.

Given that upwelling systems are the sites that dominate primary production in the global ocean, and that about 50% of the global fishing catch is taken in them, we still know surprisingly little about why they show so much variability, either internally or between the different systems. The first two sections review coastal and open-ocean upwelling systems in terms of aspects of their physics, chemistry and biology, and the fate of sedimenting particles. While these are fairly straightforward, they cover data from all major upwelling systems and discuss many important questions on how upwelling systems work: what, for instance, controls the forcing and variability of poleward undercurrents? How, and in which direction (onshore, offshore, or both) does bottom transport occur below eastern boundary currents? What dominant factors control the growth succession of phytoplankton in upwelling systems? What limits the production in the Southern Ocean? Does terrigenous input or bottom water oxygen content affect organic carbon deposition, burial, and diagenesis? And so on. In most cases no absolute conclusions can presently be drawn, but there are many pointers to possible methods of elucidating some of the answers.

Some of these questions are important in terms of defining the possible role of upwelling systems in the global carbon system. The dominance of onshore or offshore bottom transport, for instance, will ultimately control how much of the vertical carbon flux is deposited below the upwelling system and how much is exported. In chapter 15, Chavez and Toggweiler estimate that upwelling systems support directly about 67% of global carbon production. This amount (4.8 Gt yr^{-1}) should have a visible effect on atmospheric carbon dioxide levels, reducing them by 1–2 ppm per year. But what happens to the sequestered carbon?

Watson (chapter 16) argues that on short-to-medium time scales ($<10^5$ yr) upwelling systems can be either sources or sinks of atmospheric carbon, depending on the ultimate source of the upwelling water. If it is derived from the deep sea by diapycnal mixing at or near the shelf edge, then these regions will be a source of atmospheric carbon dioxide because of the large excess of dissolved gas in deep water. If, however, they are derived from shallower sources, such as subantarctic surface water (Toggweiler et al. 1991), then the sea is a sink. Given that most upwelling in eastern boundary currents and along the equator occurs from depths of 200–300 m, while almost all southern hemisphere water above, say, 1,000 m (the approximate depth of the bottom of the Antarctic Intermediate Water layer) is derived from subantarctic surface water, this may seem a moot point. Below western boundary currents, however, shelf-edge mixing appears to be more intense and to mix water from deeper in the water column to the surface. The location of the sites of such deep upwelling is at present a thorny problem for physical oceanographers, particularly given the results of diapycnal mixing experiments with inert tracers (Ledwell et al. 1993). At longer time scales, of course, all upwelling systems are net sinks for carbon, although changes in (e.g.) volcanic activity or terrestrial weathering rates can overwhelm any variation in atmospheric carbon dioxide resulting from upwelling variability. Thus, the role of upwelling systems as controls or modifiers of atmospheric carbon dioxide remains unclear.

The attempts at answering questions 3 and 4 are, to my mind, less successful than for questions 1 and 2. This is perhaps not surprising, given that each step in the pathway upwelling-production-deposition-burial-diagenesis takes us further from the