

Preface

The biological composition and richness of most of the Earth's major ecosystems are being dramatically transformed—to a significant extent irreversibly—by anthropogenic activity. The oceans form a considerable sink for heat and carbon dioxide, and ozone-related increases in UV-B radiation can negatively influence many aquatic species and ecosystems. At the same time, terrestrial flooding and polar meltwaters contribute to the freshening of many coastal regions, while land run-off brings chemical pollutants and nutrients that can lead to eutrophication and the development of harmful algal blooms and hypoxic 'dead zones'. Human activities, such as offshore construction and the transport of cargo using ships, also generate novel sound fields that can affect species behaviour. Marine environments are particularly vulnerable to such changes because approximately 40% of the world's population live within 100 km of the coast, yet a significant proportion of these inhabitants also depend on the ocean for food, economic prosperity, and well-being. Consequently, the cumulative effect of multiple stressors on ecosystems is now a major source of concern to society and is fast becoming a prominent research goal, attracting interest from those tasked with managing the environment or developing environmental policy.

Understanding and predicting the combined impacts of single and multiple stressors is, however, particularly challenging because observed ecological responses are underpinned by a number of physiological and behavioural responses that are affected by the type, severity, and timing of stressors, yet integration between the traditional domains of physiology and ecology is fragmented and often focused towards a specific set of circumstances. Environmental or comparative animal physiology texts either treat the subject area system by system, moving, for example, from cardiovascular responses to nerve and muscle function, or by considering the challenges posed by specific environments, such as polar or estuarine

habitats. Similarly, most general ecology-based textbooks, across a range of systems, provide only superficial considerations of environmental stressors, tending (in a marine context) to deal mainly with the adjustments required to survive or tolerate changes in temperature, salinity, oxygen, and/or pressure. Hence, the purpose of this book is to provide in a single volume an overview of the physiological and ecological responses of marine species to a wide range of potential stressors resulting from contemporary anthropogenic activity, while referencing the effects that this may have for the oceans, other systems, and for human well-being.

Recent syntheses of the available literature continue to present strong evidence that the cumulative effect of multiple stressors on a variety of marine species and habitats tends to be variable (additive, antagonistic, and synergistic effects), but they also reveal that the suite of effects brought about by individual anthropogenic forcing has been poorly represented in experimental manipulations. Indeed, it is clear from the literature that individual studies tend to refrain from considering physiological and behavioural mechanisms alongside the ecological and societal significance of their findings, and that studies tend to be either ecologically or physiologically themed. Our vision in compiling this volume was to provide a gateway to targeted and authoritative information within a discipline, while presenting alternative perspectives in relevant sister contributions. In doing so, we focus on eight stressors (salinity, hypoxia, ocean acidification, temperature, chemical pollution, nitrogen deposition, ultraviolet radiation, and noise) that are particularly prevalent in coastal and shelf sea environments, before offering perspectives on the concepts of thresholds and tipping points with just social foundations, economic valuation of stressor-mediated change, and, considering the many sectors of human society that utilize the oceans, how best to manage multiple stressors for society as a whole.

In order to cover both physiological and ecological aspects as well as the societal implications, we have brought together a range of expertise from within the marine community, including early career researchers and established leaders in the field, and combined this with internationally recognized researchers from the fields of physiological processes and ecological systems to broaden the scope and generic value of the volume. Collectively, the authors have broad interests across many different marine species (animals/plants/microbes) and habitats, and cover a range of technical expertise including environmental physiology and ecological theory, mathematical modelling, statistics, empirical and field research, social science, economics, and policy. Throughout, there is an emphasis on the species and communities that are the most affected, such as marine calcifiers in the case of ocean acidification and marine mammals in the case of noise pollution. Consideration is given to the damage caused by each pollutant, whether this is morphological or biochemical, and the means by which some species can recover, as well as the energetic implications that have far-reaching consequences by influencing the function and survival of populations and hence marine communities and ecosystems. Common themes

include differences in sensitivity to specific stressors among taxa, species, and life stages, and the logistical challenges represented by introducing additional stressors to experiments, along with requirements to provide local, regional, and global perspectives. The requirement for laboratory experiments to be carried out alongside, and be informed by, field and 'natural' experiments wherever possible is also apparent. Overall, we envisage that this book will be a valuable reference for students, researchers, and those tasked with conserving or managing marine systems in both the natural and social sciences by outlining our current but patchy understanding of the complex interactions between various stressors faced by species, populations, and communities, and informing on future avenues for experimentation and observation using a combination of both laboratory and field-based studies.

Martin Solan and Nia M. Whiteley

Acknowledgement

We are particularly grateful, in no small measure, to the administrative support provided by Natalie Tulett, University of Southampton, in the compilation of this book.