# Preface

When I first started out working in this field, I participated in a series of conferences in the 1970s and 1980s, organized by John and Winona Vernberg of the University of South Carolina, and Anthony Calabrese and Fred Thurberg of the NOAA laboratory in Milford CT, in which marine biologists interested in organismal biology started examining responses to pollutants. These were small meetings of around 100 people, and were among the most stimulating and enjoyable meetings I have participated in. This was an exciting beginning of a new field of study. The participants were physiologists and other biologists who had not been trained in "aquatic toxicology," as that field was still in the early stages of development. These meetings resulted in a series of peer-reviewed volumes with titles that were variants on "Physiological Responses of Marine Organisms to Pollution," but each volume had a somewhat different title, thus using up many possible titles I might have used for this book. At around the same time, another group of people, as yet unknown to me, were establishing the field of "aquatic toxicology" with a goal of developing "standard toxicity tests." I first came upon this approach when I was speaking with some EPA people about the interesting variation we had seen in killifish embryos exposed to the same concentration of mercury – some females produced very sensitive embryos and others produced very tolerant ones. I asked if they might be interested in funding further research into this intriguing observation. The response was "Could you turn this into a toxicity test?" I had no interest in toxicity tests; I merely wanted to follow up an interesting observation and learn what was going on. As it turned out, I pursued the research without EPA support. I also learned that much of the work going on in the field, unlike the research of the people who came to the "Vernberg meetings" focused on lethality as an endpoint – the "kill 'em and count 'em" approach. These projects calculated the $LC_{50}$ for different chemicals, numbers that were used in the development of regulations. Even today, research papers are still coming out with this kind of data, using a new species or different conditions. A paper entitled "Effects of X {chemical} on Y (species)" might very well turn out to be how much of chemical X was needed to kill 50 % of species Y. I find this uninteresting, and think it unfortunate for two reasons: (1) Scientists are intelligent creative people who should be developing new hypotheses and expanding the intellectual range of the field and should not be wasting their time doing this sort of routine work – the field is in need of progress and advancing along more scientifically sophisticated routes. (2) Regulatory agencies should not be relying on such crude measures for setting criteria and standards. The science has advanced far beyond this, and we know a lot about subtle sublethal responses as well as delayed responses. Setting numbers on the basis of dividing 96 h $LC_{50}$s by some arbitrary number is an antiquated approach. If this approach to standard setting is no longer being used, why are people still doing this kind of work?

Another aspect of the field is the rapid development over the past few decades of biochemical and molecular approaches. The search for new biochemical "biomarkers" of exposure or response to contaminants is a major part of the field. This reductionist approach leads to greater insight and understanding of the mechanisms by which chemicals produce effects on organisms. For the past 30 or so years there has been a series of relatively small meetings, comparable to the early "Vernberg meetings," called "Pollution Responses in Marine Organisms" (PRIMO). The papers presented at these meetings are almost exclusively biochemical and molecular. Even newer approaches are genomic and other types of "omic" approaches. However, the connection between these biochemical responses and an effect at the organism level is often difficult to draw. How does it affect the life of the animal that it is producing more or less of a certain enzyme? The study of physiological, developmental, and behavioral effects that are the focus of this book are whole animal responses that are easily related to effects at the population level, and their ecological significance is more obvious. While these kinds of studies have been somewhat overshadowed by the biochemical/molecular approaches in recent years, it is my earnest hope that they will remain active and essential components of the field, as they are the best way to link to effects on the ecosystem. This book does not cover biochemical, molecular and 'omic studies, including immunotoxicology and genotoxicology. For the topics covered there is a very extensive literature, so the book is not exhaustive, and of necessity many studies have not been included.

The marine environment is under assault from overfishing, habitat loss and pollution from increasing types of sources. New kinds of pollutants ("contaminants of emerging concern") include both new pollutants and old pollutants that no one ever paid attention to before. These include pharmaceuticals which are designed to have effects on the body at very low concentrations – so they can have effects on marine life at low concentrations also. The unsightly volumes of marine debris, often persistent plastic, washing up on beaches and collecting in Great Garbage Patches in the Atlantic and Pacific Oceans is something that most people have heard about. New awareness of the damaging effects of loud noise on marine animals, especially mammals, is a great concern as it may relate to cetacean beaching incidents. There have been a huge number of papers coming out in recent years on effects of ocean acidification. While many focus on effects on shell formation/calcification, since it is the most obvious problem caused by lower pH, people are also investigating and uncovering effects on physiology and behavior as well. Fortunately for this field, the toxicity testing folks have not gotten involved, and I am happy to report that I have not come across any publications that determine how low the pH has to be in order to kill half of the test animals. Perhaps the most widespread and serious type of pollution worldwide is eutrophication resulting from excess nutrients, which stimulates algal blooms and results in hypoxia. On a global scale, eutrophic/hypoxic areas are increasing, and there is considerable research into the sublethal effects of low D.O. on marine organisms. On the other hand, there is some “good news” in that many persistent organic pollutants have been banned and are no longer manufactured in many countries (even though as legacy pollutants they still persist in sediments, accumulate in marine life, and exert effects). Also, the frequency of oil spills has gone down in the past few decades. In addition to this reduction of inputs of some of the historical pollutants, efforts have begun to physically remove highly contaminated sediments from some of the estuarine toxic hot-spots in the U.S. under the auspices of the Superfund Program. After decades of delay, sediments highly contaminated with dioxins, PCBs and mercury are finally being removed from the Passaic River in New Jersey and other notorious sites through Superfund remediation programs.

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