
Preface

In the early twentieth century, the field of larval ecology materialized into an independent discipline of study. The following decades brought tremendous advances in the appreciation and understanding of larvae, including the sheer morphological diversity, mechanisms of feeding, and processes of metamorphosis. The conceptual framework of larval ecology as a field was not summarized until the end of that century, when the late Larry McEdward edited a 13-chapter volume entitled *Ecology of Marine Invertebrate Larvae* (1995). Now, following more than two decades of development, we have decided to organize an update for many of the chapters featured in *Ecology of Marine Invertebrate Larvae* as well as reviews of several new directions the field has taken. Because many of the chapters in this volume are highly integrative and cover many different species as well as approaches, we grouped them conceptually into four sections: (1) Evolutionary origins and transitions in developmental mode; (2) Functional morphology and ecology of larval forms; (3) Larval transport, settlement and metamorphosis; and (4) Larval ecology at the extremes.

Section 1, Evolutionary origins and transitions in developmental mode: In Chapter 1, Claus Nielsen provides an overview of the diversity of larval types from groups of marine invertebrates as diverse as the echinoderms, crustacean, and annelids, as well as emphasizes some of the central hypotheses regarding the evolution of larval types and how they evolved in the first place. In Chapter 2, Heather Marlow provides a detailed overview of the evolutionary development of marine larvae. She revisits the question, "What is a larva?" and guides her discussion by comparing specific sensory structures of the planktonic life form and how

it provides unique insight into how gene regulatory networks may have diversified over evolutionary time in patterning the larval body. In Chapter 3, Dustin Marshall and colleagues revisit questions of parental investment and life history trade-offs, as originally addressed by Vance, McEdward, and others. These important questions, as they have for decades, continue to have a fundamental influence on the life history theory of marine larvae. In Chapter 4, Rachel Collin and Amy Moran primarily discuss transitions in developmental mode. Namely, while planktotrophy (feeding) and lecithotrophy (nonfeeding) have largely dominated this discussion in the past, a thorough phylogenetic approach, using broad taxon sampling provides exciting new evidence for how these primary modes of development and feeding may have changed over evolutionary time. Lastly, in Chapter 5, Jonathan Allen and colleagues summarize the current understanding of asexual reproduction by larvae, including the diversity of developmental strategies and environmental factors eliciting a cloning response.

Section 2, Functional morphology and ecology of larval forms: In Chapter 7, Bruno Pernet reviews fundamental principles for mechanisms of larval feeding, as well as detailing the specifics for more than a dozen phyla of marine invertebrates. He then compares rates of feeding and performance for many larval types in nature. In Chapter 8, Justin McAlister and Benjamin Miner outline the phenotypic plasticity of feeding structures in marine invertebrate larvae. They discuss the evolution and molecular underpinnings of this trait, as well as proper experimental design and statistical analyses. Finally, in Chapter 9, William Jaekle focuses his chapter on the physiology of larval feeding: he

begins with the ingestion of a food particle or dissolved organic material and ends with the delivery and assimilation of the associated biomolecules.

Section 3, Larval transport, settlement, and metamorphosis: In Chapter 11, Jesús Pineda and Nathalie Reyns define and discuss larval transport, both as a concept and as a measurement. In doing so, they provide an overview of components of larval transport, from behavior to advective and diffusive processes, as well as present challenges the field faces and emerging approaches to combat these challenges. In Chapter 12, Peter Marko and Michael Hart provide a lucid discussion of approaches for genetic analysis of larval dispersal and population connectivity. They discuss the use of genetic data in characterizing connectivity, the differentiation of individual- vs. population-based methods, and the utility of isolation-by-distance patterns and dispersal kernels. In Chapter 13, Jason Hodin and colleagues emphasize the integration of fluid dynamics and sensory ecology, across spatial and temporal bounds, in the process of settlement and metamorphosis to holistically assess how larvae use diverse cues to find settling grounds. Finally, in Chapter 14, Jan Pechenik discusses latent effects, the embryonic and larval experience and its influence on life after metamorphosis. He outlines how abiotic and biotic stressors that larvae face shape this experience, as well as begins to detail how many mechanisms mediating these consequences remain unknown.

Section 4, Larval ecology at the extremes: In Chapter 16, Craig Young and colleagues assess larval transport patterns in the deep-sea and the ecological and evolutionary constraints on such patterns. They specifically hypothesize how these environments may select for specific reproductive and larval characteristics in these vast habitats. In Chapter 17, Maria Byrne and colleagues shift our perspective of larval evolutionary ecology toward the predicted future ocean, by outlining how marine invertebrate larvae are affected by ocean warming and acidification, as well as the interaction between these stressors. They discuss how a changing oceanic climate favors poleward movement, and why certain larval types may be more resilient to these stressors than others. In Chapter 18, Ilaria Corsi and Luis Fernando Marques-Santos discuss how toxicants affect embryonic and larval functionality with a focus on

the ABC transporters of echinoids. They provide a history of ABC transporters, discuss the utility of echinoids in ecotoxicology research, and emphasize the need to find complementary models. In Chapter 19, Elizabeth Williams and Tyler Carrier provide an -omics-focused perspective on marine invertebrate larvae. Specifically, they outline the use of a multi-omics approach in deciphering the molecular mechanisms of life history evolution and the resiliency to environmental stress, as well as new fronts in the field, including characterizing larval-associated microbiota. In Chapter 21, we conclude the volume with a summary of its contents from Richard Strathmann and Alan Love, who propose how marine invertebrate larvae continue to collectively serve as a model for studying life history evolution.

The editors and many of the chapter authors who contributed to this edited volume would like to acknowledge the impact that *Ecology of Marine Invertebrate Larvae* (McEdward, 1995) had on our research interests and, indeed, even on our decisions to pursue science as a profession. We anticipate that research utilizing marine invertebrate larvae will continue to grow, and just as the previous two decades have opened up new avenues in research since McEdward (1995), the coming years will continue to bring new ways to understand marine invertebrate larvae. If this book can have even a small impact on promoting the growth of the field, then we will feel this project will have been successful. As a field, we still know surprisingly little about vast numbers of marine invertebrates, including whole phyla in some cases, and parts of the globe remain virtually unexplored. Lastly, marine invertebrate larvae have at different times in history held particular sway in the understanding of central questions in biology, ranging from macro-evolution of life histories to cell differentiation, developmental pathways, and gene regulatory networks; the time may be ripe, again, for larvae to take center stage.

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