*Journal of Chemical Ecology, Vol. 28, No. 10, October 2002(© 2002)*

## *PREFACE*

# THE NEXT WAVE IN AQUATIC CHEMICAL ECOLOGY

MARK E. HAY*

*School of Biology*
*Georgia Institute of Technology*
*Atlanta, Ga 30332-0230 USA*

Aquatic chemical ecology is a recent, but dynamic and rapidly developing, discipline that has become a recognized field only within the last two decades. As an example, a 2001 book on marine chemical ecology (McClintock and Baker, 2001) lists thousands of references with nearly 90% being post-1982 and about 50% being post-1992. Prior to the 1980s, some chemists were exploring marine organisms for novel secondary metabolites and some ecologists were documenting patterns that appeared to be chemically-mediated, but it was uncommon for the chemistry and ecology to be rigorously merged. In the 1980s, marine chemists and ecologists began collaborating to explore types of chemically mediated interactions that had been investigated previously in terrestrial systems (e.g., consumer–prey interactions). These studies benefited greatly from the intellectual infrastructure of terrestrial investigations and models. However, aquatic investigations also provided increased depth to the general fields of chemical ecology, community ecology, and evolution by: (1) testing theories derived for terrestrial systems in evolutionary independent aquatic systems; (2) assessing the ecological function of secondary metabolites under field conditions where investigators did not need to rely on assumptions about the important consumers, primary selective pressures, or relative roles of consumers vs other selective agents; and (3) integrating the specific metabolites and interactions being investigated into a larger community-based framework so the cascading effects of chemically mediated interactions on marine diversity and community organization could be understood. Most initial studies focused on understanding the ecological or evolutionary consequences of prey chemical defenses—an area well represented by terrestrial investigations. This

*E-mail: mark.hay@biology.gatech.edu



0098-0331/0U1000-1897/0

provided opportunities for a host of marine–terrestrial contrasts that advanced our understanding of chemical ecology in both aquatic and terrestrial systems.

In addition to studies of defense, investigations of chemically mediated foraging, habitat selection, induction of metamorphosis, host–symbiont interactions, and mate tracking and recognition have been conducted in aquatic systems. To be ecologically realistic, these investigations often demand complex integration of behavior, sensory ecology, chemistry, hydrodynamics, and micro- or molecular biology. Achieving such integration is an obvious challenge, but significant advancements are being made, and the field seems poised to merge these disciplines in ways that will provide rigorous mechanistic insights into major processes regulating populations and affecting the structure and function of entire communities.

The mini-reviews presented in this issue attempt to demonstrate both the exceptional opportunities and significant challenges involved in aquatic chemical ecology. In recent years, comprehensive reviews focused on chemical-mediation of biotic interactions in aquatic systems have become a growth industry (e.g., Hay and Fenical, 1988; Davis et al., 1989; Paul, 1992; Pawlik, 1992, 1993; Hay, 1996; Weissburg, 2000; Zimmer and Butman, 2000; McClintock and Baker, 2001). Given these recent summaries, the mini-reviews requested for this issue were targeted at research areas in the early stages of development, but demonstrating great promise. Authors were challenged to be strategic rather than comprehensive in their coverage and to focus more on opportunities, challenges, and needs than on summarizing previous investigations. The mini-reviews, therefore, represent a terse synopsis of dynamic areas within the field, along with a call for focused investigations that will shape the future.

The reviews champion greater focus on: (1) the underlying physiological and molecular basis of metabolite synthesis, turnover, and deployment; (2) chemical mediation of interactions among microbes and between microbes and hosts; (3) understanding how hosts can use chemical signals to regulate microbial behavior (rather than survival via antibiotic activity) as a defense against enemies or to facilitate mutualist microbes; (4) an appreciation of the ontogeny of chemical defense among organisms with complex life-cycles, and the repercussions of this for the evolution of life history and behavioral traits; (5) understanding how the flow environment in which interactions occur may facilitate or hinder consumer foraging and prey escape via affects on transmission and detection of chemical signals; (6) employing a nonreductionist approach that tests for emergent responses to suites of multiple, and sometimes conflicting, chemical cues; and **(7)** elucidating the cascading effects of secondary metabolites on nontarget organisms and how these effects may impact larger scale patterns such as food-web structure, community composition, rates and pathways of biogeochemical cycles, and the coupling of aquatic with terrestrial systems.

Although the questions and approaches outlined in these mini-reviews are general, they are addressed in systems (e.g., freshwater, the plankton), life stages

(e.g., larvae), or organisms (e.g., marine microbes) where previous investigations have been adequate to demonstrate exciting possibilities, but where much progress is needed and now possible. The authors of these mini-reviews focus on exciting subdisciplines that are just beginning to flourish. It is hoped that the excitement and significant opportunities presented in these reviews will stimulate other investigators to accept the intellectual and methodological challenges noted by these authors and push the field forward to new frontiers.

## REFERENCES

DAVIS, A.R., TARGETT, N. M., MCCONNELL, O. J., and YOUNG, C. M. 1989. Epibiosis of marine algae and benthic invertebrates: natural products chemistry and other mechanisms inhibiting settlement and overgrowth. *Bioorg. Mar. Chem.* 3:85-114.

HAY, M. E. 1996. Marine chemical ecology: What is known and what is next? *J. Exp. Mar. Biol. Ecol.* 200:103-134.

HAY, M. E. and FENICAL, W. 1988. Marine plant-herbivore interactions: the ecology of chemical defense. *Annu. Rev. Ecol. Syst.* 19:lll-145.

MCCLINTOCK, J.B. and BAKER, B. J. 2001. Marine Chemical Ecology. CRC Press, Boca Raton, Florida.

PAUL, V. J. 1992. Ecological Roles of Marine Natural Products. Comstock Press, Ithaca, New York.

PAWLIK, J.R. 1992. Chemical ecology of the settlement of benthic marine invertebrates. *Oceanogr. Mar. Biol. Annu. Rev.* 30:273-335.

PAWLIK, J.R. 1993. Marine invertebrate chemical defenses. *Chem. Rev.* 93:1911-1922.

WEISSBURG, M. J. 2000. The fluid dynamical context of chemosensory behavior. *Biol. Bull.* 198:188-202.

ZIMMER, R. K. and C. A. BUTMAN. 2000. Chemical signaling processes in the marine environment. *Biol. Bull.*