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Editorial

ECOTOXICOLOGY OF ANTICHOLINESTERASE PESTICIDES: DATA GAPS AND RESEARCH CHALLENGES

Organophosphate and carbamate insecticides have replaced organochlorines in many countries as the most important line of defense against agricultural pests and disease vectors. Although these cholinesterase-inhibiting compounds are less persistent in the environment and have lower mammalian toxicity than their chlorinated predecessors, they still pose risks to nontarget organisms and ecological systems. The unintended impacts of these pesticides have been investigated for decades, but many important details regarding environmental exposure and toxicological response are still poorly understood. In November 2004, a special session convened at the SETAC World Congress in Portland, Oregon, USA, to address some of these gaps in our knowledge.

A core objective of applied ecotoxicological research is to generate new scientific information that will allow natural resource managers to make more informed decisions about the risks that pesticides pose to nontarget organisms. From the standpoint of assessing risk, this means a better understanding of exposure as well as a more detailed understanding of toxicological response in different species and at different scales of biological organization. The aim of the special World Congress session was to advance the state-of-the-science on both of these fronts.

In the context of exposure, it often can be prohibitively expensive to monitor intensively the environmental concentrations of pesticides across broad spatial and temporal scales. This reality can make it very difficult to estimate exposure conditions for highly mobile animals, such as birds and anadromous fish. Temporal limitations on monitoring also constrain exposure estimates for amphibians and other wildlife that rely on broadly dispersed, ephemeral wetlands for breeding habitat. Thus, an important and ongoing challenge is to estimate pesticide exposure at the landscape scale in the absence of measured environmental concentrations. Here, Mineau and Whiteside (pp 1214–1222) develop a novel approach for birds based on agricultural land-use patterns across the United States. Using estimated pesticide application rates for specific crops, they show how chemical exposure and associated risk of mortality can vary for birds across large geographical areas.

In the context of toxicological response, a long-standing challenge has been to measure meaningful biological outcomes in response to environmentally realistic exposures, particularly in the low-dose range [1]. Although cholinesterase inhibition is an established biomarker of exposure, the depression of enzyme activity alone is not particularly informative unless it can be linked to endpoints with clear significance for the survival and lifetime reproductive success of nontarget organisms. These traits ultimately determine the fitness of exposed animals and, by extension, the dynamics of natural populations. A related challenge is the need to develop novel endpoints that take into account variation in life-history strategies across species [2] and that adequately capture responses to sublethal pesticide exposures. The emphasis on sublethal endpoints is important, because sublethal exposures typically are much more common than those that cause outright mortality in natural systems. Finally, because organophosphate and carbamate insecticides often co-occur in the environment, the combinatorial toxicity of these chemicals as mixtures needs to be evaluated as well. Here, Scholz et al. (pp 1200–1207) test the hypothesis that the individual components of mixtures are additive in terms of inhibiting acetylcholinesterase derived from the nervous system of chinook salmon.

Because pesticides usually enter aquatic systems as nonpoint-source pollutants, understanding the significance of short-term, transient exposures is particularly important for aquatic species. In this series, separate studies by Duquesne, Andersen, and their colleagues (pp 1187–1199) show that reproductive success in *Daphnia magna* is reduced after pulsatile exposures to cholinesterase inhibitors. Both studies also explore the impacts of pulsatile exposures on *D. magna*. The results of these studies have implications for zooplankton populations and for planktivorous predators that rely on these aquatic invertebrates for food. The complexity of community-level changes resulting from the cascading ecological effects of pesticides is an increasingly important focus of recent research [3–5].

Behavioral performance is particularly important to the survival of many organisms, and traits related to locomotion may be informative as indicators of sublethal, anticholinesterase-induced neurotoxicity. Here, Hopkins and Winne (pp 1208–1213) explore the swimming performance of four species of snakes following exposure to a carbamate insecticide. Based on their findings, they suggest that gross motor control in snakes may be relatively insensitive to cholinesterase inhibition and that future studies should focus on other, more subtle changes in animal behavior with relevance to fitness (e.g., response to predators, courtship interactions).

In summary, organophosphate and carbamate pesticides continue to enter and, at times, degrade the habitats of native species around the world. In the United States, increasing concern exists surrounding the impacts of these chemicals on vulnerable species, including threatened and endangered populations of birds, reptiles, amphibians, fish, insects, plants, and many other organisms (see, e.g., [6]). In most cases, these species have not been traditional test organisms in modern toxicology. To have the greatest relevance for management of at-risk species, the spatial and temporal scales of pesticide exposure, the interactions between pesticides and other stressors (chemical or nonchemical), and the environmental realism of exposure concentrations should be considered carefully in the experimental design of future ecotoxicological studies. Similarly, ecological risk assessments for anticholinesterase

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pesticides will benefit from studies that address novel taxa, toxicity of mixtures, sublethal effects that clearly influence individual fitness, and indirect or cascading ecological effects of pesticides in complex communities.

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