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This symposium on mosquito control was born out of the suggestion last July by Governor Perpich that we should take a look at statewide mosquito control as a means of boosting the tourist trade and bringing dollars into the state economy. The governor's suggestion was quickly supported by the Minneapolis *Star and Tribune* and by others who foresaw an easy fix to a statewide nuisance.

The suggestion of border-to-border treatment of Minnesota with insecticides brought shivers down the spines of those of us who remember firsthand the ecosystem-wide poisoning of our land by DDT and related chemicals in the two decades after World War II. What we did then was done partly in ignorance and partly in stupidity. The ignorance, at least, has been dissipated to some extent by that bitter experience, and we now understand that one key to the probability that any chemical insecticide will be environmentally harmful is the persistence of the compound in the environment. Will it be broken down to harmless compounds quickly by natural processes? If the answer is no, then the likelihood of environmental damage is increased. So we see little pressure today to revive the use of persistent insecticides on a big scale. But part of the problem in the 1950s was lack of understanding by policy-makers and by the general public of some basic principles of ecology. Even today we must ask, how well are these principles understood? What are these principles?

First, application of any insecticide or other material that substantially reduces the numbers of diptera (mosquitoes along with houseflies, midges, deerflies, and other flies) and other insects in wetlands will have an effect on fish, amphibians, reptiles, birds, and mammals, for the simple and inescapable reason that these aquatic insects are an important part of the food web. If the insects are gone or reduced, there is less food for other animals to eat. The only valid question is, how much of an effect? not, will there be an effect?

Second, all materials used today for mosquito control affect beneficial insects as well as the nuisance species. The most important predators on insects are usually other insects. While we are killing mosquitoes, we are also killing predatory insects that would have killed mosquitoes if left alive. This makes the net benefit of control programs more difficult to measure.

In fact, no aspect of population ecology has received more careful study and mathematical analysis than predator-prey relationships. It turns out that if predators and prey are in balance, then the application of a general insecticide that affects both the prey and the predators will have a surprising effect. The prey will increase because of the increase in the predator death rate. The predator will decrease because of the decrease in the intrinsic rate of increase of the prey. The net result will be an increase in the abundance of the pests themselves, exactly the opposite of the effect intended by the application of the insecticide. This effect is called the Volterra principle, and it applies to any system in which the abundance of the predators is controlled mostly by the growth rate of the prey and the abundance of prey by the death rate of the predators.

Third, any control program that kills some but not all individuals of the affected species will have an evolutionary effect if there is any genetic (that is, heritable) difference influencing which individuals survive and which die.

It is this principle, selection through differential mortality, that has led to the astonishingly rapid evolution of pesticide resistant insects, of which over 300 kinds have now been identified. Mosquitoes around the world are becoming resistant to a wide range of insecticides. As resistance evolves, higher doses of insecticides are needed to get results; these higher doses speed up the whole vicious circle, until finally the chemical can no longer be used effectively. The evolution of pesticide resistance could be slowed if control programs were limited to situations where genuine public health problems are involved and not used in those where mosquitoes are merely a nuisance.

Consider the materials used in mosquito control. Abate and Dursban are organophosphates that are lethal to a wide range of invertebrates as well as insects. Both are also toxic to birds, mammals, fish, amphibians, and humans; the toxic effect depends on exposure. Aside from direct toxicity, these compounds affect survival of all vertebrates that rely on insects for food, either directly or secondarily. Resmethrin is a pyrethroid compound, not very toxic to birds and mammals, but highly toxic to fish, amphibians, and all insects, not just the relatively few target species that are pests. To their credit, mosquito control programs today use biological controls and growth regulators where possible, but the fact is that the chemical insecticides are still important weapons in their arsenal. Because they are not lethal only to mosquitoes, these materials have biological effects on any treated ecosystem far beyond reducing the mosquito population. Again, the appropriate questions are, how great are the undesired effects? Is their cost offset by the benefits of killing mosquitoes?

Physical modification of wetlands by ditching or by altering the permeability of the clay basin of small ponds has also

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been suggested as a means of mosquito control. There is no question that this would eliminate mosquito breeding spots, but it is hard to imagine any procedure more permanently destructive to the wildlife that depends on the wetlands. If we value wetlands and wildlife so little, we might as well pave the state with asphalt. We might then see clearly the importance of wetlands not only to wildlife but also to flood control, groundwater recharge, erosion control, and pollution abatement.

In response to Governor Perpich's suggestion that we investigate the possibility of statewide mosquito control a task force called the Minnesota Mosquito Research Program was established in the Department of Health. The task force has prepared a report to the governor stressing the importance of research—baseline monitoring of the environment—before any expanded control program is implemented. We can all agree that this is the prudent response. But we must be sure that the research that is done measures up to high scientific standards. It won't be enough to look at only one or two species in the hope that they will be accurate indicators of the effect of any control program. Natural communities are complex in their interrelationships, and understanding of these interrelationships will not come from simplistic approaches to monitoring.

The current mosquito control program in the metropolitan area is an unfortunate example of an overly simplistic approach. The program was started without any preliminary environmental monitoring. Once in place, such programs preclude the opportunity to make even the most obvious before-and-after treatment comparisons. The basis for measuring the effect of any control program should be in place before the actual control begins.

To some extent, the call for more research may merely obscure what we already know but are unwilling to act on. Shades of acid rain, where our current federal administration resists desperately needed action by calling for more research on a topic on which the general facts are already painfully clear. We already know that the agents now used to depress mosquito populations have a wide range of other biological effects. We know that the materials with broad toxic effects have a greater potential for biological disruption. We know enough to predict with certainty that any statewide control program using the chemical insecticides used now in the metropolitan area at levels high enough to have a major depressing effect on mosquitoes will affect the fauna of the state on a scale unprecedented in our history.

Thoughtful citizens in Minnesota realize that mosquito control is not free. In addition to millions of dollars, the price includes reduced populations of songbirds, ducks, fish, frogs, and a great array of other creatures. The questions that can't yet be answered, are how great a reduction are we talking about? Is it so trivial that we can afford to ignore it? We do not know. Even the current level of control in the metropolitan area seems to some biologists to be extracting an unacceptable price for the supposed benefits. We need to document the biological cost of the current efforts before we even begin to consider expanding control efforts to the whole state.

The current enthusiastic promotion of mosquito control is eerily reminiscent of the boosting of DDT and its chemical relatives in the 1950s and 1960s. Then as now, environmentalists who protested were dismissed as sentimental and uninformed. Only people who are 50 years old or older will easily remember the biological horrors of those decades; songbirds in DDT tremors falling from city shade trees, bald eagles, ospreys, brown pelicans, and peregrine falcons suffering from reproductive failure through DDT-induced eggshell thinning. Each of us today carries DDT in our bodies as a reminder of that unfortunate era. Minnesotans were spared the most visible effects of DDT use—the large scale poisoning of songbirds through spraying of city elm trees to prevent Dutch elm disease. Dutch elm disease did not reach Minnesota until the early 1960s; the general use of DDT had already been banned by the time Dutch elm disease control programs were started here in the 1970s.

We can't escape the consequences of arrogant and ignorant environmental policies once they are in place. The best we can hope for is to avoid them by the most intelligent public consideration we can bring to the problems facing us. That is the purpose and goal of the symposium covered in the following pages.