ECOTOXICOLOGY
TOPIC FACT SHEET

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What is ecotoxicology?

Pesticides and other contaminants that get into the natural environment can affect wild plants and animals. The science of studying these effects is called ecotoxicology.[1] Ecotoxicology is a mix of ecology, toxicology, physiology, analytical chemistry, molecular biology, and mathematics. Ecotoxicology looks at the impacts of contaminants including pesticides on individuals, populations, natural communities, and ecosystems. Communities of living things and the environments they live in form ecosystems. Ecosystems include ponds, rivers, deserts, grasslands, and forests, and they too can be affected by pesticides. Ecotoxicologists also study what happens to the pesticides themselves, where they go in the environment, how long they last, and how they finally break down. This fact sheet will focus on pesticides in ecotoxicology.

Fate, transport, and exposure

A pesticide may directly affect something far from the site of application. Pesticides that are bound to soil particles may be carried into streams with runoff. Pesticide drift may travel many miles in the wind. Sunlight, water, microbes, and even air can break down pesticides.

Some pesticides last a long time in the environment, and may pose risks to living things many years after they were last used. Insecticides such as DDT, chlordane, and dieldrin don't break down easily, and they are still found in soil, plants, and animals. Persistent pesticides may travel long distances in the air or water, or even in living organisms such as migrating birds or fish. Researchers have found pesticide residues in alpine lakes and snow, many miles from where the pesticides were applied.[2,3] Pesticides have even been found in the Arctic and Antarctic environments, probably carried there by currents in the atmosphere or oceans.[4,5]

Plants may absorb pesticides through their roots or leaves. Animals can be exposed to pesticides directly by breathing them in, getting the pesticides on their skin, or eating them. Pesticides may fool animals; granules may look like food to wild birds especially.[6] Unfortunately, this has actually happened and birds were poisoned as a result.[7] Sometimes an animal's food may be contaminated from pesticide residues in plants or in the tissues of prey. **Secondary poisoning** can occur if an animal eats another animal that has been fatally poisoned by a pesticide, and predator dies as a result of the poisoned prey. This is also called **relay toxicosis**.

Some chemicals cross the skin, lungs or gills, and intestine more easily than others. When scientists evaluate the uptake and activity of pesticides in the body, they call it **bioavailability**. A pesticide's bioavailability depends on whether it is soluble in fat, whether it might be stored in other tissue such as bone or the liver, and how difficult it is for the body to break down the pesticide and excrete it.[1]

Pesticide build-up in living tissue

Pesticide residues build up in organisms and in food webs. **Bioaccumulation** can occur if residues build up faster than the organism can break them down and excrete them. Bioaccumulation in aquatic animals where the pesticide is taken in from the water is called **bioconcentration**.[1] If a predator eats many plants and/or animals that have pesticide residues in their tissues, the predator may suffer from even greater exposure than the prey. Bald eagles, ospreys and peregrine falcons were brought to the brink of extinction because their food sources (fish and other birds) were contaminated with DDE, the breakdown product of the insecticide DDT. The residues built up with each link in the food chain until very high concentrations were present in the eagles, falcons, and ospreys. When residues increase in the food web, the process is called **biomagnification**.[1] No single exposure for either the prey or the predator is likely to cause injury, but the overall effects can be very harmful.

Effects may be specific to time and place

The timing of exposure can greatly affect how much damage a pesticide might cause. Migrating animals may use a stopover site or staging area only briefly. At that time, those special locations may harbor a large proportion of the population or even the entire species. Other animals form breeding colonies for a few weeks or months of the year. Examples include some species of bats and swifts. If a pesticide is used when and where wildlife are clustered together, much greater harm could result than if that application occurred at another time even in the same place.

Risks may also increase at certain times in the animals' lives. Pesticides may pose greater risks to young animals or animals under stress from migration or breeding. The life stage of a plant may affect its risk of harm. An herbicide may not hurt a seed, or cause only small damage to a large, vigorous plant. However, it might kill a seedling.

Exposure risks may also depend on the conditions in a certain place. For example, barn owls eat voles when they are available.[8] When voles are scarce, barn owls are more likely to eat other rodents such as rats and house mice. Rats and house mice are more likely to carry traces of pesticides. Dead and dying prey may be easier to catch and eat.[9] That means the risks to barn owls depend on what is happening within the rodent community, which affects what prey the barn owls are likely to catch.

Effects on individuals and populations of organisms

Pesticides can affect individual plants and animals in two ways. First, they may cause injury or death after the plant or animal is exposed to the pesticide directly. This might happen if the pesticide drifts onto the plant or animal, the animal breathes in the pesticide, or if the animal drinks or eats something that is contaminated. Plant roots may pick up pesticides in the soil. Any injuries resulting from these exposures are called **direct effects**. The second way pesticides may cause harm is by changing or killing something the plant or animal needs. For example, pesticides can affect an animal's food supply by killing certain plants or insects. The loss of plant cover may also remove the animal's shelter. Plants could be affected if their pollinators or seed-dispersers are killed. These are **indirect effects**.

A pesticide does not have to kill an organism to do harm. Instead, a pesticide may have **sublethal effects** such as making the organism sick, changing its behavior, or changing its ability to reproduce or survive stress. If enough individuals die without leaving behind enough offspring to take their places, the population gets smaller. For example, young salmon exposed to pesticides do not grow or survive as well as unexposed fish. Over time, this could affect salmon population numbers.[10] Pesticides could affect a population through direct or indirect, as well as lethal or sublethal effects.

Community effects

Effects can also occur on larger ecological scales than that of the individual. For example, predator-prey relationships may be changed by pesticides and other contaminants.[11] If the predatory wasps are more affected by an insecticide than the pests they feed on, the pest population may grow. The population of pests will often recover faster than the populations of predators following pesticide applications in agriculture.[11]

When pesticides remove one of the species at the bottom of a food web, many other species may be affected. In this example of community-level effects, spraying for mosquitoes with *Bacillus thuringiensis israelensis (Bti)* reduced the populations of midges and mosquitoes, the favorite food of house martins. House martins in treated areas made fewer trips back to their nest with food, and raised fewer young, than house martins living in untreated areas. Spiders and dragonflies declined in treated areas, probably because they also eat midges and mosquitos.[12]

Declines in the number of one species may also affect plants or other organisms. For example, if a butterfly's host plant is affected by pesticides, they may not have enough places to lay eggs. If a pollinator species is lost, plants may not be able to set enough seed to maintain their numbers. These indirect effects can be very difficult to predict without doing experiments.

Researchers put together large containers for stream insects and earthworms, and they added leaves from trees that were treated with the insecticide imidacloprid. Aquatic insects and microbes decomposed fewer leaves from the treated trees, and the earthworms lost weight compared to controls. Treated leaves were therefore not as quickly broken down by earthworms as the control leaves were.[13] This study demonstrated a sublethal effect on decomposers by affecting their feeding behavior, which led to indirect effects on the whole community because of the slower breakdown of the leaves.

In another study, researchers created ponds made from watering tanks, placing plants and animals inside that would be found in an ordinary pond. When they sprayed some of the tanks with the insecticide malathion, many effects occurred. The number of tiny aquatic animals called zooplankton declined in the treated tanks. Zooplankton feed on phytoplankton, tiny floating plants. Phytoplankton increased when zooplankton densities declined, and blocked light penetration to the bottom of the tanks. Algae and other organisms growing on the bottom died from lack of light. Leopard frog tadpoles had less food, and grew more slowly. This made them more likely to die as the ponds dried up. An effect that ripples through a community like this is called a **trophic cascade**.[14]

Another study studied the relationship between parasitic flatworm infections in leopard frogs and pesticides in water. The concentration of atrazine, a common herbicide, was directly related to the number of parasites infecting the leopard frogs. When atrazine was added to the tanks, it killed the phytoplankton. More sunlight reached the bottoms of the tanks, allowing periphyton to grow. More snails were able to live in those tanks. The flatworms use snails as hosts before they infect the frogs, so more snails meant more flatworms. The scientists concluded that the atrazine indirectly increased parasitism in the frogs by increasing the population of snail hosts.[15]

At the ecosystem level

Pesticides and contaminants may affect more than just the populations of animals and plants that make up a community. They may also affect basic processes like nutrient cycling or the formation of soil. For example, nitrogen cycling may be affected if pesticides impact the bacteria and fungal communities in soil.[16] There may be a time lag between the pesticide exposure and the ultimate effects. The pesticide could be gone before the damage it caused also disappears.

How are products evaluated for their risks to the environment?

In the United States, the Environmental Protection Agency (U.S. EPA) reviews all pesticides before the products are registered for sale. They require companies to submit the results from standard toxicity tests as part of the application for registration. Depending on how and where the products are going to be used, companies may have to conduct more or different types of studies. A product meant only for use in someone's home may not require toxicity tests on fish. That information would be required for a product that will be applied on aquatic weeds. The U.S. EPA registers pesticides when the benefits outweigh the risks, assuming products are used according to the label directions.

What can I do?

When you are deciding whether or not to use a pesticide, balance the potential benefit against the potential costs, including environmental impacts. Sometimes using a pesticide, even according to its label, may cause harm. When that's the case, it is up to the user to weigh the costs and benefits, and if necessary, choose not to use the product.

If you use a pesticide, always be sure you read and follow all label instructions exactly. It will reduce the risk, but it won't necessarily prevent accidents. Read the environmental hazards part of the label carefully. Could use of this product harm bees or bats, or is it very toxic to fish? If so, and if fish or bees could be exposed, you might consider finding another product. Try to find the least toxic product that will do the job. It may be possible to take care of your pest problem using ***integrated pest management***, which may mean using fewer pesticides, or possibly none at all.

You know your application area best. If you know certain spots are important places for special plants or wildlife, try to prevent contamination of those sites, especially at critical times of the year. You may also contact your state wildlife agency or the US Fish and Wildlife Service for more information. There are many federal and state laws protecting migratory birds, animals, and rare plants, but the most important protections come from ordinary people taking steps to avoid accidental harm.

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