

Effects of Pesticides and Contaminants on Neotropical Migrants

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Abstract — Many agricultural pesticides and industrial contaminants are capable of adversely affecting birds through direct effects such as elevated mortality rates and decreased reproductive success or indirectly by modifying habitat composition or food availability. Although neotropical migrants are potentially exposed to these contaminants on their breeding, migratory and wintering habitats, the impact of pollutants on population declines of migrant species is poorly understood. We review the effects of these contaminants on birds, evaluate the ability of current monitoring techniques to detect and assess the magnitude of exposure, and suggest research and management needed to improve our understanding of the contribution of environmental pollutants to population declines of neotropical migratory birds.

INTRODUCTION

Substantial quantities of pesticides and industrial contaminants are released into the environment every year, both intentionally and accidentally. Many of these chemicals become distributed over vast geographical regions either due to widespread usage or movement through environmental compartments. As a result, contamination or modification of many ecosystems occurs, with the subsequent potential for adverse effects on the biota inhabiting those ecosystems. Migratory bird species are potentially be exposed to a wider range of pollutants than non-migratory species, as their annual movements can bring them into contact with pollutants in breeding and wintering regions and on migration routes. However, our understanding of the contribution of pesticides and pollutants to population declines of neotropical migrants is hindered by a lack of knowledge on the extent to which migrants are exposed to these chemicals and the importance of pollutant-induced changes in mortality and reproductive success relative to other anthropomorphic or natural factors which may also affect population size.

This report briefly summarizes the potential effects of pesticides and pollutants on birds, discusses the issues which monitoring techniques must address to detect and assess the magnitude of these effects, and comments on the potential contribution of contaminants to population declines of neotropical migratory birds.

MODES OF EXPRESSION OF TOXIC EFFECTS

Pesticides and contaminants exert their toxic effects on birds in varying manners depending upon their chemical nature, environmental persistence, mode of action and methods by which they are metabolized in birds. Even within any class of contaminants, toxic effects may be expressed differently depending on the magnitude of exposure, and environmental conditions under which exposure occurs.

Acute toxic effects are exhibited following brief exposures to single or multiple doses of a chemical. Mortality is a typical response to acute doses of many pesticides, although other responses may include behavioral or reproductive alterations. Chronic effects are exhibited after a long period of uptake of small amounts of a toxicant. Chronic effects may be expressed in many forms including reproductive or behavioral changes, immunological impairment, carcinogenesis, and teratogenesis. Chronic effects often do not become apparent until after the source pollutant has disappeared or may be a response to very

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low concentrations of a pollutant, therefore it may be more difficult to establish cause and effect relationships following chronic exposure than following acute poisonings.

Direct effects are changes induced in a bird following exposure to a xenobiotic, with increased mortality, decreased reproductive success, increased susceptibility to predation or behavioral impairment being among the most common. Indirect effects are responses to pesticide-induced changes in food resources, habitat structure and predator or competitor abundance. Since changes in habitat structure or animal abundance may not occur until a considerable period after the exposure event, the relationship between cause and effect may not be readily apparent.

CONTAMINANTS OF CONCERN

There are five major classes of environmental contaminants which may be most likely to affect neotropical migrants:

1. *Organochlorine pesticides and related industrial contaminants*

This group encompasses the chlorinated hydrocarbon insecticides (e.g. DDT and analogs, dicofol, dieldrin, aldrin, endrin, hexachlorocyclohexanes, mirex, heptachlor), and related industrial contaminants (polychlorinated biphenyls (PCBs), dioxins and furans) which display similarities in environmental fate and biological effects. These compounds typically have low acute toxicity, and the greatest risk to wildlife is due to their chemical stability which confers prolonged environmental persistence. The nonpolar chemical structure of these chemicals causes them to partition into lipids and bioaccumulate in food chains with resulting biomagnification in wildlife (Risebrough 1986).

2. *Organophosphorus and carbamate insecticides*

These compounds are widely used in North America for insect pest control in agricultural, rangeland and forestry applications (Szmedra 1991), and use in Latin American countries is apparently increasing (Forget 1991). These compounds exert toxic effects by binding to and inhibiting acetylcholinesterase (AChE) enzyme at synapses in the central and autonomic nervous systems and at nerve endings in striated muscle. AChE regulates normal nerve function by hydrolyzing the neurotransmitter acetylcholine (ACh) at nerve synapses. These compounds generally have low environmental persistence, but their acute toxicity has resulted in numerous avian die-offs which may cause local population perturbations (Grue et al. 1983).

3. *Herbicides*

Herbicides are generally non-toxic to birds, but can have a severe impact on avian populations since they produce extensive habitat modification (Morrison and Meslow 1983). Habitat alterations may require years to have their greatest effect on bird populations, whereas the direct effects of herbicides on plants may be observed more rapidly. Consequently, secondary and

tertiary effects of herbicide use within terrestrial communities may be more difficult to relate back to the original cause, but have long-term consequences for avian species.

4. *Acidic Precipitation*

Impacts on birds using acid-stressed ecosystems are likely, particularly indirect effects due to changes in habitat structure or prey availability (Blancher 1991). Habitat acidification can also increase the bioavailability of several non-essential, potentially toxic metals, including mercury, aluminum, cadmium, and lead, which can move through food chains to piscivorous and insectivorous birds (Scheuhammer 1991).

5. *Metals*

Metals have high environmental persistence because natural cycling in the environment is extremely slow. Metals have the ability to bioaccumulate through food chains, especially in aquatic ecosystems. Only about 30 metals are considered toxic, and of these the ones of greatest toxicological concern include mercury, cadmium, aluminum, lead and selenium. Dietary exposure to some metals can lead to reproductive dysfunction or increased susceptibility to disease at levels too low to cause acute effects (Scheuhammer 1987).

ASSESSMENT OF THE EFFECTS OF TOXICANTS ON NEOTROPICAL MIGRANTS

The likelihood that a pollutant will detrimentally affect neotropical migrants is governed by numerous factors including its chemical and physical properties, environmental movement and fate, and ecological and behavioral traits of individual species that alter their probability of coming in contact with the pollutant. To address these factors requires a multi-stage assessment procedure which provides either quantitative or qualitative rankings of ecological risk (US Environmental Protection Agency 1991). Some stages of this procedure will require the expertise of environmental chemists or toxicologists. The crucial role of the field biologist or ornithologist will be to integrate toxicological and environmental contamination data with a thorough knowledge of the ecological and behavioral characteristics of individual species to predict which species are at greatest risk.

The preliminary phase of the procedure involves hazard identification to determine which chemicals are present in the habitat or ecosystem of interest. Identification may be based on environmental sampling, a knowledge of regional pesticide use patterns and industrial emissions or on the basis of information pertaining to known or suspected past pollution events. When chemical identification is complete, the magnitude and frequency of release of those chemicals into the environment and their spatial and temporal distribution patterns need to be quantified. This is a particularly important step, since the risk to avian populations from chemicals with localized distributions or which are present only at times when migrants are absent from the contaminated area is likely to be low. Concentrations of the

chemicals or metabolites should be measured, and evaluated to verify whether they are in a bioavailable form, or are sequestered in environmental compartments where they are unavailable to birds.

When the presence of a chemical has been confirmed, biologists can undertake an exposure assessment to decide which species are most liable to come in contact with the pollutant. Previous field studies or toxicity data derived from laboratory experiments may help in evaluating which species are most sensitive to the pollutant, and whether the concentrations present are sufficient to elicit toxic effects. However, in most cases, very little is known about the toxic effects of pesticides and pollutants on migratory passerines. Extrapolating toxicology data from other species may give an indication of the potential toxic responses, but inter-specific variability is often great, and such extrapolations should be undertaken with caution.

Birds are exposed to xenobiotics via ingestion, dermal absorption and inhalation, with ingestion (either through food consumption or preening) being the most important route. The extent of exposure is moderated by the environmental persistence of the chemical and the magnitude and frequency of its release into the ecosystem. A thorough understanding of the behavioral and ecological traits of individual species greatly improves the ability to estimate the extent of exposure. Habitat use of a species will determine whether it occupies an ecosystem or area where the contaminant is present. For chemicals with low environmental persistence, seasonal and annual movement patterns will determine whether presence of a species in an area coincides with presence of the active compound. Since ingestion is a primary route of exposure, diet and feeding habits will greatly influence which species are most apt to come in contact with the chemical. If sufficient toxicological and ecological information exists, researchers should be able to integrate both sets of data to predict which species are at greatest risk of exposure, and therefore potentially warrant investigation for contaminant-induced population effects. However, since our present understanding of the toxic effects of contaminants on migrants is limited, that predictive capability is likely to be poor in most cases.

When exposure is known or suspected, verification can be obtained from a variety of quantitative measurement endpoints. Selection of the appropriate measurement endpoint is important. For example, tissue residue analyses would be inappropriate for chemicals which do not bioaccumulate or which have low persistence. At the cellular level, use of contaminant-induced biochemical and physiological changes as markers of exposure and environmental quality are becoming increasingly popular. At the organismal level, mortality, reproductive performance, behavioral changes, and carcass contaminant residues are commonly utilized measurement endpoints. An important consideration, however, is that none of these measurement endpoints are necessarily indicators of adverse effect. The ultimate endpoint of concern is whether exposure is responsible for population declines. The value of any measurement endpoint from an ecological viewpoint will ultimately depend on being

able to correlate observed changes with population level effects. Predicting population level effects from residue levels or biomarker responses is not a straightforward process, however. In order for measurement endpoints to provide valuable risk assessment data, quantitative models need to be developed which permit extrapolation to population level responses (Emlen 1989).

While an assessment procedure such as that outlined above could prove useful in determining the impact of xenobiotics on neotropical migrants, several problems hinder widespread applicability at present. First, characterization of the extent of environmental contamination is far from complete, both in terms of the types of contaminants present and extent of their distribution. This is particularly valid for Central and South American regions where migrants winter, but also applies in many regions of their North American breeding ranges. Second, there are probably very few instances where polluted areas are subject to only one chemical stress, and when multiple contaminants are present, synergistic or additive effects of compounds can occur. The toxic effects of exposure to several chemicals simultaneously are often difficult to predict from effects elicited by chemicals acting individually. More importantly, chemical stresses typically occur in ecosystems subject to other anthropomorphic, non-chemical stresses such as habitat conversion or fragmentation. The contribution of contaminants to population declines observed in many migrant species relative to these other pressures may be difficult to determine. Finally, as noted previously, many chronic or indirect effects of contaminants may not become obvious until long after the pollution event has occurred, and cause and effect may not be readily apparent.

MONITORING TECHNIQUES

We currently lack sufficient information to satisfactorily evaluate the effects of xenobiotics on population dynamics of neotropical migrants. An appropriate first step to strengthen hazard assessment procedures would be the collection of baseline data on contaminant levels in migrants. Subsequent research should attempt to correlate that data with changes in mortality and fecundity rates or population abundance. Comprehensive monitoring programs are required to provide this baseline data.

Several non-lethal monitoring techniques can provide useful information. Blood samples obtained from birds trapped in mist-net studies or banding programs can be analyzed for organochlorine residues, because levels in blood are indicative of levels in other tissues (Henny and Meeker 1981). Plasma can also be assayed for the presence of certain metals such as lead. Metal residues in feathers have also been used as indicators of contamination (Scheuhammer 1987). Plasma can be easily assayed for cholinesterase activity, which is a sensitive indicator of exposure to organophosphorus and carbamate insecticides (Hooper et al. 1990).

Incident monitoring involving collection of mortalities following pesticide applications or pollution events allows for testing of carcasses for the presence of pesticides or residues. This is a simple, but effective, means of assessing actual poisoning incidents. Various federal and state agencies use incident monitoring schemes which vary widely in effectiveness due to differences in scope, data collection methods and funding (Avian Effects Dialogue Group 1989). This form of monitoring can create useful databases of contaminant-induced bird mortality, but a lack of reports is not indicative of no adverse effects since geographic coverage is not uniform, and sublethal effects are rarely studied. Standardized data collection methods are required in order for incident monitoring programs to reliably document the frequency of mortality incidents and their potential impact on avian populations.

A more comprehensive form of monitoring, targeted monitoring, incorporates design and implementation of planned field studies to evaluate potential acute and subacute effects of contaminants on bird populations under actual exposure conditions.

In order for monitoring programs to provide pertinent data for estimating contaminant effects on migrants, several criteria must be met. Monitoring programs must cover a broad geographic range and incorporate a diversity of ecosystems to successfully demarcate the extent of contamination. Since this range must encompass breeding, wintering and migratory habitats, collaboration between agencies or researchers in various countries will be essential. Programs must also operate on a multi-year basis to document long-term trends in contaminant levels. For pollutants with limited environmental persistence, however, monitoring must be precisely timed in order to detect effects that occur immediately after the chemical is released into the environment. All monitoring programs must also include an ecosystem-based hazard identification component to quantify what contaminants are present, and their concentrations, transport and fate in the ecosystem.

Since monitoring programs can not be created for all neotropical migrants, it will probably be necessary to select several focal species which can serve as indicators of exposure to, and toxicity of, contaminants for other migrants. A suitable focal species must be sufficiently abundant, easily manipulated, and possess ecological and behavioral characteristics similar to those of other migrants. It is also important that focal species display representative sensitivity to contaminants, however that will be difficult to evaluate until more research focuses on the toxic effects of contaminants in migrants. Monitoring of focal species should be conducted year-round, and should evaluate reproductive success, mortality rates, habitat use and behavioral characteristics in addition to assessing contaminant levels.

Finally, evaluations of pesticide effects on birds are typically based on acute effects such as mortality, while often overlooking the more subtle sub-acute effects. Therefore, for all species, population censusing techniques are required which are sensitive to sublethal effects of pesticides, and which incorporate evaluations of reproductive success. Population-level effects of

some pesticides may not have been well documented in previous studies due to inappropriate census methods (Mineau and Peakall 1987).

CONCLUSION

Pollutants and pesticides are widely distributed in the environment. Despite our current lack of knowledge on contaminant loads of these chemicals in migrants, it is very likely that birds are being exposed to at least some of these chemicals, and it is reasonable to expect that some adverse effects are occurring. The importance of the role of contaminant exposure to population declines in neotropical migrants relative to other anthropomorphic stresses is difficult to quantify at present. In order to improve our understanding of the effects of environmental pollutants the following research and management needs must be addressed: 1) expansion and standardization of monitoring programs; 2) selection of appropriate neotropical migrants as indicator species; 3) improvement of hazard identification procedures in wintering regions and on breeding habitats; 4) assessment of sublethal impacts of contaminant exposure; and 5) development of quantitative population models which incorporate appropriate ecological and toxicological data to predict the effects of environmental contaminants on population dynamics of neotropical migrants.

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