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Environmental Contaminants and Colonial Waterbirds

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Despite the existence of numerous statutes and guidelines regulating the use of chemicals and anthropogenic processes, environmental contaminants and pollution pose a significant risk to colonial waterbirds and their supporting habitat. The extent of damage caused by pesticides, industrial chemicals and metals to biota is related to both the magnitude of exposure and the nature of the toxicant. Ecological Risk Assessment is a recommended method for assessing the threat of individual or combinations of chemical and physical stressors to colonial waterbirds. Screening and definitive field studies can be undertaken to evaluate exposure (chemical residues in tissues and biomarker responses indicative of contaminant insult) and adverse effects (mortality, aberrant behavior, and alteration of recruitment and survival), and thus characterize and manage the risk to local, regional and even continental populations of colonial waterbirds. In addition to abatement of environmental contaminants and pollution threats at their source, number of management and habitat manipulation techniques can minimize bioavailability or exposure to hazardous chemicals, and thus mitigate their adverse effects.

Discussion of the Issue

Source and Issue

As a consequence of extensive chemical use and pollution, colonial waterbirds are unintentionally exposed to a variety of pesticides, economic poisons, industrial chemicals, manufacturing byproducts, petroleum crude oils, metals, metalloids, and radionuclides. Exposure to anthropogenic environmental contaminants, as well as potentially toxic naturally-occurring elements and compounds, is often associated with acceptable and even licensed practices (e.g., application of pesticides, irrigation, mining, discharge of industrial effluents, aerial emissions associated with manufacturing). In addition, exposure can also occur following accidental spills or discharges, and on rare occasions purposeful and illegal poisoning of wildlife that are perceived to be nuisance species. There is no doubt that certain environmental contaminants and polluted habitats have affected local, regional, and even continental populations of some colonial waterbird species. Moreover, some contaminants have been linked to the endangerment and near extinction of several species of birds.

Science

Ecotoxicology is the science of predicting effects of potentially toxic substances and pollution on natural ecosystems and nontarget species. Controlled studies have demonstrated that environmental contaminants and some naturally-occurring elements are toxic to wildlife, and when "*biologically available*" in ecosystems, they can pose a significant threat to colonial waterbirds. The magnitude of adverse effects range from minor sublethal perturbations to dramatic and well-documented episodes of mortality with population level consequences. Furthermore, alteration of food chains and destruction of critical wildlife habitat have often been a consequence of environmental contamination. The extent of damage to individuals, populations and communities, are generally viewed to be a function of the *magnitude of exposure* and the *nature of the toxicant* (i.e., "the dose makes the poison"). A few examples are provided to demonstrate this axiom.

1. In the 1940's, the use of environmentally persistent organochlorine pesticides (e.g., DDT and dieldrin) became widespread. "Long-term" dietary exposure (months to years) to these bioaccumulative pesticides resulted in some direct mortality of juvenile and adult individuals. However, it was the "lipophilic nature" of these pesticides (particularly the DDT metabolite *p,p'*-DDE) that resulted in their transfer into the egg and caused the more devasting population-level effects attributable to eggshell thinning, embryo mortality, and decreased reproductive success (Blus, 1996; Custer, 2000). In contrast, the more contemporary organophosphorus and carbamate insecticides are rapidly metabolized in the environment and do not accumulate in food chains. For "short-periods" (days to weeks) following application, birds may be

exposed by various routes, including ingestion of dead or struggling insects in treated fields or wetlands. Occasionally, episodes of localized nestling, juvenile and adult mortality (a few to thousands of individuals) occur following application of these pesticides (Grue et al., 1983), with the suspected cause of toxic exposure ranging from a combination of unusual environmental factors to outright pesticide mis-application. However, these cholinesterase-inhibiting insecticides, and for that matter other contemporary agrichemicals, are not readily transferred into the egg. Unlike effects of organochlorine pesticides, potential population and community level effects are more frequently attributed to "indirect effects" on food abundance and habitat, rather than "direct toxic effects" on reproduction.

1. Collection and reuse of irrigation water is a common agricultural practice. Starting in 1978, irrigation water collected from drain tiles beneath fields with seliniferous soils was conveyed via the San Luis Drain to the Kesterson National Wildlife Refuge in California. Concentrations of selenium in the drainwater, and subsequently in the aquatic food webs utilized by birds, became dramatically elevated. Selenium is a naturally occurring trace mineral essential for normal physiological function in vertebrates. However, when the "safe" dietary concentration of selenium was exceeded for a sustained period, this "essential nutrient" became "toxic", which resulted in embryonic deformity of epidemic proportion and impaired recruitment in some species of colonial waterbirds (Ohlendorf and Hothem, 1995).

3. Petroleum hydrocarbons enter the environment from a variety of sources, including natural seeps, fires, urban run-off, and industrial and transportation spills and discharges. Without a doubt, the most dramatic exposure events involve tanker crude oil spills such as the *Exxon Valdez*. Following such incidents, birds may be affected by ingestion of petroleum, egg oiling, and habitat destruction. However, unlike many "invisible" toxicants, it is the conspicuous external oiling of plumage and destruction of insulatory function that results in hypothermia and drowning of countless individuals. Spilled petroleum can act through a number of toxic mechanisms resulting in immediate and long-term effects on populations, particularly those with low reproductive rate.

Regulation

Chemical use and anthropogenic activities that liberate naturally-occurring toxicants are an integral part of civilization as we know it. In the past 40 years, society has become more enlightened and recognized that environmental stewardship is a component of sustainable development. Numerous local, national and international statutes and regulations have been developed that set standards and attempt to insure the safe use and mobilization of chemical substances. For example, in the United States, the Federal Insecticide, Fungicide, and Rodenticide Act and the Toxic Substances Control Act mandate that adequate data be generated and evaluated on the hazard and benefit of pesticides and industrial chemicals to humans and the environment (including *nontarget biota*). Such statutes are usually proactive, although all too often ongoing use of a chemical is canceled or banned after its actual environmental hazard is more fully recognized. There are a number of statutes that more directly protect wild birds. The International Migratory Bird Treaty Act broadly states that without regulations permitting an activity, the destruction of birds, their nest and eggs is an unlawful activity for which punitive measures may be imposed. The Endangered Species Act requires protection of wildlife threatened with extinction, and can have a direct bearing on chemical use that could affect select biota or their supporting habitat. The Fish and Wildlife Coordination Act requires that wildlife conservation receive equal consideration with other features during planning and decision making processes that may impact waterbodies including wetlands. There are also statutes that provide a mechanism to remediate environmental contamination and restore habitat once damage has occurred (e.g., Comprehensive Environmental Response, Compensation and Liability Act and Natural Resource Damage Assessment Act). Despite the existence of all of these statutes, their enforcement is fraught with difficulty, and at times their value is dubious.

Approaches Taken and Recommended

The likelihood that adverse ecological effects are occurring as a result of exposure to one or more stressors may be evaluated by Ecological Risk Assessment (ERA)(USEPA, 1998). This process examines data, information, assumptions and uncertainties in order to understand and predict the relationship between chemical, physical, or biological stressors and ecological effects. The two major elements of this process include characterization of exposure and characterization of effects, and help focus problem formulation, analysis and risk characterization. The overall effort expended in conducting an ERA should be consistent with the perceived magnitude of the problem. Results of an ERA, along with social, economic, political and legal issues, can be used by waterbird practitioners and risk managers as part of a cost-benefit analysis. In addition, results of an ERA can identify alternative chemicals or processes to mitigate risk.

Assessing Exposure and Effects

Characterization of contaminant exposure and effects is the cornerstone of ERA. These elements of ERA are often initially examined by "screening field studies" that evaluate evidence of exposure (e.g., residues in tissues, biomarkers responses) and overt signs of toxicity (e.g., mortality, aberrant behavior, sublethal physiological effects, changes in species density and diversity). Subsequently, "definitive field studies" are undertaken that include additional assessment endpoints such as reproductive success and survival. Such studies are replicated in time or space, or examine exposure and effects along a gradient of contamination. The ultimate goal of these assessments is to determine the linkage between ecological effects (e.g., impaired reproduction in a colonial waterbird species) and a stressor of varying intensity (e.g., an environmental contaminant) in an effort to establish evidence of causality. Controlled exposure studies in surrogate species may also provide information to establish causality. For example, decline in the population status of the brown pelican (*Pelecanus occidentalis*) was evaluated through field studies of *p,p'*-DDE residues in eggs (measure of exposure) and eggshell thinning and hatching success (measures of effect), and in controlled reproductive studies with captive mallards (*Anas platyrhynchos*) and American kestrels (*Falco sparverius*) receiving diets containing *p,p'*-DDT and *p,p'*-DDE (Blus, 1996). Thus, measures of exposure and effect at the level of the individual were used to predict effects on an assessment endpoint (population viability of piscivorous birds) and establish causality.

Mitigating Contaminant Hazards to Colonial Waterbirds

Chemical manufacturers have long since adopted product stewardship and responsible management practices. Product data undergo extensive review by manufacturers and government officials that can result in regulation or restriction of its use. New methods and processes (e.g., waste minimization, recycling, Integrated Pest Management) are continually sought to minimize the environmental hazards of chemicals. Other anthropogenic activities (e.g., dredging, development and road construction) often undergo extensive evaluation, review, and permitting in an effort to minimize their effects on the environment. Nonetheless, situations arise that threaten waterbirds and their supporting habitat.

There are a number of techniques that can be employed to limit use of a contaminated site (Dolbeer et al., 1996), and thus minimize exposure to hazardous substances. These include use of sound emitting devices (e.g., propane cannons, exploders, shell crackers, rockets, whistle bombs, recorded alarm or distress calls), visual deterrents (e.g., avoidance of "colored" baits, inanimate hawk kites and owls), chemical repellants (e.g., taste aversive agents, avitrol and other chemical frightening agents that cause distress calls and erratic behavior, and even poisons), and physical barriers (e.g., screening, overhead lines and wires). Although many of these methods have been used successfully, often species habituate, learn, or modify their behavior in a manner that perpetuates toxicant exposure. Perhaps the most important and practical technique is to minimize exposure by habitat manipulation (e.g., modification of water level, ground cover, and nesting structures, use of buffer strips, and provision of alternate habitat).

Occasionally, exposure to a hazardous substance can be greatly diminished or eliminated. For example, hazardous sites can be capped with clay or covered with a synthetic membrane, thereby greatly restricting bioavailability of contaminants. Chemical release rates into environmental media may be reduced below adverse effect thresholds (i.e., "dilution is the solution to pollution"). In rare instances, approved use of a pesticide or industrial chemical is severely restricted or canceled altogether. Such decisions are usually based on concerns for human health. With the exception of population and community level effects of DDT, regulatory decision involving wildlife and environmental contaminants have been based on overt injury to individuals. Unfortunately, some banned chemicals are highly persistent (e.g., DDT, polychlorinated biphenyls, dioxins), and thus exposure may continue for decades after their cancellation.

Practical Recommendations

To follow are suggestions that may facilitate the assessment and mitigation of chemical risks to colonial waterbirds:

1. Consider utilizing ERA methodology for hazards that are perceived to be affecting local, regional and continental populations of colonial waterbirds. Enlist help from a team of professionals (e.g., biologist, ecotoxicologist, statistician, analytical chemist, risk assessor) to assist with the assessment.

2. Spend adequate time during the problem formulation phase of the ERA to generate and evaluate hypotheses about if, why, and how chemical hazards may be affecting colonial waterbirds and their habitat. Develop a conceptual model with written and visual representations.

3. Hold organized public meetings, with representation from government, industry, academia, conservation organizations and concerned citizens, at appropriate phases of ERAs and when developing risk management plans.

4. Undertake “screening field studies” before initiating “definitive field studies”. Be prepared to collect biotic and abiotic samples for costly and time consuming contaminant analysis in order to characterize chemical exposure, and to monitor behavior, reproduction, and survival of colonial waterbirds to characterize potential effects.

5. When characterizing chemical risks to colonial waterbirds, recognize that environmental contaminants are only one of many stressors that impact biota and habitat. Managing chemical risks to colonial waterbirds may have social, economic, and legal ramifications. Recognize that the results of cost-benefit analysis may yield a solution that is displeasing to biologists.

6. Be pragmatic and seek simple solutions to perceived contaminant threat. Occasionally, a *simple* management action can abate a serious chemical hazard.

A Few Guiding Principles

Colonial waterbird managers need to be cognizant of local, regional, and continental patterns of chemical use and anthropogenic pollution. Such information is available from diverse sources, and can serve to focus initial evaluations of potential hazards.

There is no doubt that some environmental contaminants and pollution processes adversely affect biota and their supporting habitat. The associated risk to colonial waterbirds is dependent on the bioavailability of the contaminant, and exposures and effects that exceed a known or theoretical threshold. If a contaminant is neither bioavailable nor appreciably disturbs supporting habitat, it poses little or no risk to colonial waterbirds.

Abatement of contaminant and pollution threats to biota are best accomplished through prevention at their source. For societal reasons however, this is often impractical. Exposure to hazardous substances and amelioration of adverse effects can be accomplished through a variety of wildlife management and habitat manipulation techniques. In some instances, governmental regulatory actions on the use of chemicals or anthropogenic processes are required to mitigate risk to biota.

Environmental contaminants and pollution constitute only one of many threats to colonial waterbirds. Combinations of chemicals and pollution processes may interact with one another, and even with other factors (e.g., adverse weather, disease, poor nutrition). Reproductive success and survival of colonial waterbirds reflect the integration of many categories of stressors and natural biological processes.

Important Books, Chapters, and Web Sites

Beyer WN, Heinz GH, Redmon-Norwood AW. 1996. Environmental contaminants in wildlife: interpreting tissue concentrations. SETAC Special Publication Series. Boca Raton, FL: Lewis. 494 p.
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Eisler R. 2000. Handbook of chemical risk assessment: health hazards to humans, plants and animals. Boca Raton, FL: CRC Press LLC. Volumes 1, 2, and 3.
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Furness RW. 1993. Birds as monitors of pollutants. In: Furness RW and Greenwood JJD, editors. Birds as monitors of environmental change. London: Chapman and Hall. p. 86-143.
Kendall RJ, Bens CM, Cobb III GP, Dickerson RL, Dixon KR, Klaine SJ, Lacher Jr TE, LaPoint TW, McMurry ST, Noblet R, Smith EE. 1996. Aquatic and Terrestrial Ecotoxicology. In: Klaassen CD, editor. Casarett and Doull's Toxicology: the basic science of poisons. NY: McGraw Hill. p. 883-905.
Hoffman DJ, Rattner BA, Burton AG, Cairns J Jr. 1995. Handbook of Ecotoxicology. Boca Raton, FL: Lewis Publishing Inc./CRC Press Inc. 755 p.
Roffe TJ, Friend M, Locke LN. 1996. Evaluation of causes of wildlife mortality. In: Bookhout TA, editor. Research and management techniques for wildlife and habitats. Bethesda, MD: The Wildlife Society. p. 324-348.
US Environmental Protection Agency. 1998. Guidelines for ecological risk assessment. Washington DC. Federal Register 63(93):26846-26924.

Web Sites

"Biological and Ecotoxicological Characteristics of Terrestrial Vertebrate Species Residing in Estuaries" >300 page web site http://www.pwrc.usgs.gov/resshow/rattner/bioeco/preamble.htm

"Contaminant Exposure and Effects--Terrestrial Vertebrates Database" 4800 record database. http://www.pwrc.usgs.gov/ceetv/

"Environmental Contaminants Encyclopedia On-line" http://www.nature.nps.gov/toxic

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Dolbeer RA, Holler NR, Hawthorne DW. 1996 Identification and control of wildlife damage. In Bookhout TA, editor. Research and management techniques for wildlife. Fifth edition. Bethesda, MD: The Wildlife Society. p. 474-506.

Grue CE, Fleming WJ, Busby DG, Hill EF. 1983. Assessing hazards of organophosphorus insecticides to wildlife. *Trans N Amer Wildl Nat Resour Conf* 48:200-220.

Ohlendorf HM, Hothem RL. 1995. Agricultural drainwater effects on wildlife in central Califorinia. In: Hoffman DJ, Rattner BA, Burton Jr AG, Cairns Jr J, editors. Handbook of ecotoxicology. Boca Raton, Florida: Lewis. p. 577-595.

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