WILDLIFE DAMAGE

DEVELOPMENT OF CHEMISTRY-BASED TOOLS FOR WILDLIFE DAMAGE MANAGEMENT

John J. Johnston from USDA/APHIS/WS/National Wildlife Research Center at Fort Collins, Colorado, USA, discusses chemistry-based tools for the management of pest wildlife including toxicants, infertility agents, attractants and repellents

Introduction

Urban and suburban conflicts between humans and wildlife are increasing in frequency (Conover and Decker, 1991). This is partially attributable to decreases in wildlife habitat as growing residential and commercial areas engulf former wildlife habitat. Additionally, wildlife populations have increased in response to protective legislation and limitations placed on direct management approaches. In the U.S. today, many rural and urban areas are inhabited by larger wildlife populations than were present a century ago (Fall and Jackson, 1998; Johnston *et al.*, 2001a).

Economic losses caused by wildlife impact many sectors of society and approach $5 billion each year (Conover *et al.*, 1995). Nearly 90% of U.S. agricultural producers experience problems with wildlife resulting in annual losses in excess of $2 billion. These include losses to crops, livestock and timber (Figure 1). Furthermore, 60% of urban and suburban households in the U.S. experience problems with wildlife amounting to annual losses estimated at $1.9 billion. Wildlife-human conflict such as deer-automobile collisions, bird-aircraft strikes, wildlife bites and wildlife vectored diseases result in approximately 5000 human illnesses and 400 human deaths each year.

Deer and geese represent growing and challenging areas of human-wildlife conflict. For example, in New Jersey, deer are involved in more than 8000 automobile collisions annually and cause more than $20 million in damage each year. Traditional effective deer control strategies include increasing hunter access to private lands and manipulating hunting seasons. While effective, these techniques are inappropriate for many suburban and urban areas. As a result, non-lethal approaches such as contraception are being developed to manage deer populations in these areas (Conover and Decker 1991).

The mission of the United States Department of Agriculture's National Wildlife Research Center (NWRC) is to develop approaches to minimize human conflict with wildlife. The majority of NWRC's resources are utilized to develop socially acceptable, non-lethal approaches to wildlife damage management. Ideally, these approaches are efficacious, economical and acceptable to both society and the agricultural industry. A variety of chemistry based approaches such as induced infertility, repellents, attractants and toxicants are currently being developed (Johnston *et al.*, 2001b).

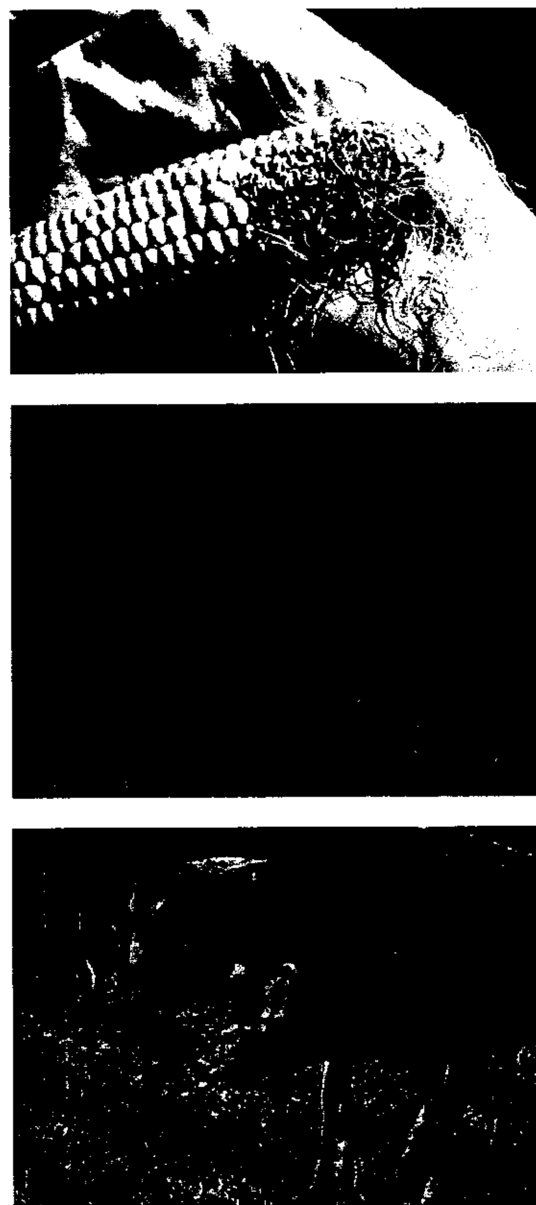

Figure 1. **Examples of wildlife induced agricultural damage: top – corn damaged by migratory birds. Middle – livestock predation by coyotes. Bottom – seedlings damaged by grazing deer.**

DOI: 10.1039/b211169c

Induced infertility

Induced infertility is a potential management tool for pest bird species such as Canada geese and white-tailed deer in urban and suburban situations. Initial research focused on inducing infertility through the use of contraceptive vaccines – agents which cause animals to produce antibodies against their own reproductive hormones (Miller and Fagerstone, 2000). However, to be efficacious these vaccines must be injected, an impractical delivery approach for controlling pest wildlife. To overcome this hurdle, smaller stable organic compounds are being investigated as possible infertility agents. These include 20,25-diazacholesterol, nicarbazin and cabergoline.

20,25-diazacholesterol

20,25-diazacholesterol inhibits the reduction of the C-24 double bond in the conversion of dehydrocholesterol to cholesterol (Johnston *et al.*, 2002a). As cholesterol is a precursor for many reproductive hormones, it is hoped that suppression of cholesterol levels in pest wildlife will induce infertility. This approach should be applicable to deer and grainivorous birds, species in which all of the cholesterol is synthesized within the body. Feeding 1% 20,25-diazacholesterol fortified feed to Coturnix quail for 2 weeks reduced the production of viable eggs by more than 80% for 6 months following the treatment period (Yoder, 2000). The mean reproductive rate in deer was reduced by 33% following oral administration of 20,25-diazacholesterol at 1 mg kg^{-1} for 3 days.

Nicarbazin

Nicarbazin is used as an anti-coccidial agent for broiler poultry. However, when fed to breeder or layer hens, nicarbazin reduces egg hatchability and/or egg production. When fed to chickens for two weeks, diets fortified with nicarbazin at 100 ppm reduced reproduction by 85%. Within one week following termination of dosing, nicarbazin was rapidly cleared from the body and reproduction rate returned to pretreatment levels (Johnston *et al.*, 2001a). Similar results have subsequently been observed in ducks and geese. As wild geese significantly reduce feed intake several weeks prior to laying eggs, the rapid reversal of efficacy presents a significant problem with respect to controlling pest goose populations. Current nicarbazin research is focusing on increasing absorption and decreasing the rate of elimination.

Cabergoline

In many instances, coyote depredation of livestock results from territorial parents provisioning for their young. This hypothesis is supported by the demonstration that surgically sterilized coyote packs predated less on sheep than unaltered coyote packs (Bromley and Gese, 2001). Oral administration of the ergot derivative cabergoline was evaluated as a more practical approach to preventing the occurrence of coyote litters. Decreased litter size was observed in all cabergoline treated groups. The maximum decrease in litter size approached 50%. Higher doses of cabergoline will be evaluated in hopes of increasing the efficiency of disrupting pregnancy in predatory canids (DeLiberto *et al.*, 2002).

Repellents

Chemical repellents can be used to minimize damage/consumption of treated objects such as electrical wiring, maple sap collection tubing or food (Johnston *et al.*, 2002b). Primary repellents produce aversion in the pest species upon initial exposure. For example, predator odors are sometimes avoided by prey. This aversion is believed to be related to sulfur-containing protein metabolites in predator urines (Nolte *et al.*, 1994). Many primary repellents also produce pain/irritation which results in an immediate response by the pest animal. Examples include the mammalian repellents capsaicins (active ingredient in "hot sauces"), ammonia and isothiocyanate (mustard oil) and the bird repellent, methyl anthranilate (a flavor component of grapes). Many primary repellents are taxa-specific. For example, the taste threshold for capsaicin is approximately 10 parts per million in mammals while birds easily tolerate concentrations of 20,000 parts per million in drinking water. Producers of bird feed capitalize on this difference by adding capsaicin to bird feed to minimize consumption by squirrels and other rodents. Similarly, rodenticides may contain the bittering agent denatonium benzoate to reduce accidental ingestion by humans.

Secondary repellents typically cause illness and require that the target species learn to avoid the associated sensory cues; tastes that are followed by sickness can be effective repellents. (Clark, 1998). Learned or conditioned avoidance using secondary repellents has been used to minimize predation of endangered Least Tern (*Sterna antillarum browni*) eggs by ravens. Quail eggs injected with the insecticide methiocarb were placed near raven nests several weeks prior to the beginning of the breeding season. Ravens ingested the methoicarb treated eggs and presumably associated the methiocarb induced sickness with consumption of eggs as Least Tern egg predation at that site was eliminated for that breeding season (Avery *et al.*, 1995).

Formulations

Chemical pesticides or drugs are rarely used in their neat form; formulations are required to increase their stability in environment, increase species specificity, permit application by a practical means and/or increase acceptance by target species. As wildlife species are typically less accessible than livestock or companion animals, it is desirable to deliver most wildlife management chemicals orally. To achieve this goal, encapsulation is applied as a means of masking the flavor of toxicants and to increase the field stability of active ingredients (Hurley *et al.*, 1999). Multiple layer encapsulated formulations are being evaluated for the oral delivery of labile drugs to pest ungulates such as deer. These formulations must afford protection in the rumen and stomach and subsequently release the active ingredient in the small intestine to permit absorption. Active ingredients have been incorporated into a synthetic grit matrix to develop a species specific controlled release formulation for management of pest birds. Following ingestion of the grit formulation, the active ingredient is released as the matrix is slowly worn down in the crop of the bird. As different species of birds select for specific ranges of grit sizes, controlling the size of the grit pieces offers a means to decrease ingestion by non-target birds.

Toxicants

Currently, there are 11 active ingredients registered as vertebrate toxicants with the U.S. Environmental Protection Agency. Rodenticide baits to control a variety of rodent pests such as pocket gophers, mice, rats, wood chucks and ground squirrels may include zinc phosphide, strychnine, diphacinone, chlorophacinone, difethialone, warfarin, bromethalin, bromadialone, cholecalciferol, pindone or brodifacoum. In addition, gas cartridge type products which are ignited to produce toxic smoke are used for the control of burrowing rodents such as pocket gophers, ground squirrels and wood chucks. Active ingredients for these products include potassium or sodium nitrate, sulfur and carbon. Baits containing 2% DRC-1339 (2-chloro-3-methylbenzamine) are registered for the control of pest birds such as gulls, pigeons, starlings and blackbirds.

Selectivity is particularly challenging for the development of wildlife toxicants. Regulatory agencies are very protective with respect to non-target risks for humans and endangered species (the majority of which are wildlife). Since humans and non-target wildlife are physiologically quite similar to the target species for wildlife toxicants (as compared to insecticides, herbicides and fungicides), humans and non-target wildlife are generally susceptible to the toxic effects of wildlife toxicants. To effect selectivity and to minimize non-target risks, bait placement strategies are often required for wildlife toxicants. These strategies may require that toxicants are used in bait stations which physically restrict non-target access to baits, or that they can be applied only when/where at-risk non-target species are absent.

Metabolism and residue chemistry

The estimation of primary and secondary non-target hazards is required for the safe use of wildlife pesticides. Primary hazards result from the consumption of pesticide baits by non-target species. Secondary hazards result from the consumption of poisoned carcasses (containing toxicant residues) by non-target species (Figure 2). Metabolism chemistry and residue chemistry provide the foundation for these hazard assessments. Metabolism studies utilize radiolabeled active ingredients to determine significant metabolites and degradation products resulting from the ingestion of the wildlife toxicant by the target animal. Field studies in which pest wildlife infested plots are treated with the wildlife toxicant are then conducted to determine the efficacy of the toxicant with respect to reducing exposed populations of the target species. Target and non-target carcasses are collected from these studies and analyzed to quantify the toxicant residue constituents. Residue methods requiring multi-stage clean-up procedures are required to quantify these constituents in whole body wildlife carcasses. These residue data are used to estimate potential exposure (and associated hazards) of non-target scavengers or predators feeding on poisoned target species.

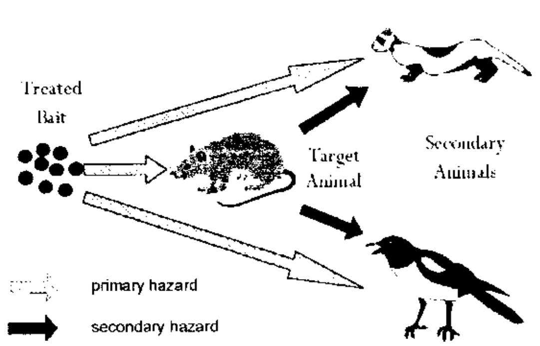

Figure 2. **Primary and secondary hazards must be considered when conducting risk assessments for pest wildlife toxicants.**

Attractants

Attractants are used to increase the efficacy of other wildlife management approaches. For example, it is generally assumed that for a contraceptive to be effective under field conditions, it must be delivered orally to the target. Evaluation of sweeteners and commercially available flavors indicated that deer preferred natural sugars to saccharine or cyclamate and that volatilized flavors increased attractiveness. However, preferences tended to be site specific, which reinforces the commonly held belief that wildlife attractants are geographically (and seasonally) specific (Bean and Mason, 1995).

Many molecules which are attractants to rats contain sulfur. These sulfur containing compounds are attractants to carnivores and omnivores because they are associated with protein digestion. Such sulfur-containing compounds hold promise for increasing consumption of baits by carnivores and omnivores (Mason *et al.*, 1994).

Traditionally, coyote attractants are comprised of mixtures of rotten meats, urines and other biological substances. Preparation of these attractants is often complex and difficult to replicate between batches. In an attempt to overcome these drawbacks, the volatiles from 33 traditional attractant mixtures were collected, identified and quantified by purge and trap coupled with gas chromatography/mass spectrometry (Kimball *et al.*, 2000). The suite of volatiles produced by the traditional attractants revealed seven types of mixtures. These mixtures were used to produce recipes for seven relatively simple synthetic attractant mixtures. When presented to coyotes, the individual mixtures elicited different responses (*i.e.* pulling, digging, rolling, rubbing, urinating, defecating). These findings suggest that attractant mixtures can be developed to enhance specific management techniques such as leg-hold trapping, snares and delivery of toxicants or drugs.

Conclusions

Chemistry based tools for the management of pest wildlife include toxicants, infertility agents, attractants and repellents. Successful wildlife management strategies often require an integrated approach which utilizes a combination of these tools. For example, toxicants may be used to reduce pest populations to a point where repellents offer significant resource protection. Attractants may be used to increase the effective application rate of wildlife vaccines or infertility agents. As such, chemistry research plays a key role in the development of effective tools for wildlife damage management.

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John Johnston graduated in 1986 with a Ph.D. from University of Florida. His dissertation research focused on the toxicity and metabolism of organophosphate insecticides to non-target marine organisms. He then joined the Environmental Chemistry and Toxicology Laboratory at University of California – Berkeley as a Research Toxicologist where he investigated the metabolism and toxicity of prototype isobutylamide insecticides to target and non-target species. In 1988, John worked for Chevron Agrochemical Co. in Richmond, CA as a Metabolism, Environmental Fate, and Residue Chemistry study director. In 1991, he joined the U.S. Department of Agriculture/Food Safety and Inspection Service as a mass spectrometry specialist charged with developing methods for detecting drugs and pesticides in meat products. Since 1994, John has been employed as the Chemistry Project Leader for the U.S. Department of Agriculture/National Wildlife Research Center where he leads chemistry based interdisciplinary research to develop new approaches to reduce wildlife damage to agriculture and other sectors of society. In his spare time, John plays slide guitar and sings blues and ragtime music in Colorado pubs and restaurants.

ADDITIONS AND CORRECTIONS

Rachel Carson (1907-1964)

Pesticide Outlook, 13(5), 204. (DOI: 10.1039/b209425h)

The author apologises for the omission of a copyright/credit line for the photograph of Rachel Carson. The photograph credit should be "Photo by Brooks Studio. Courtesy of the Lear/Carson Collection".

Acrylamide in food linked to herbicides

Pesticide Outlook, 13(5), 182. (DOI: 10.1039/b209409f)

This news item was based on a report by the Institute of Science in Society (http://www.i-sis.org.uk/acrylamide.php).