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Introduction

Wildlife Services—Vision and Strategic Goals

The mission of Wildlife Services (WS), formerly Animal Damage Control, is to provide Federal leadership in managing problems caused by wildlife. The National Wildlife Research Center (NWRC) functions as the research arm of WS by providing scientific information for the development of socially acceptable methods for wildlife damage management. As part of WS' strategic plan to improve the coexistence of people and wildlife, it has identified four goals: (1) Developing Methods, (2) Providing Wildlife Services, (3) Information and Communication, and (4) Valuing and Investing in People. WS is dedicated to helping meet the wildlife damage management needs of the United States by building on its strengths in these four key areas. NWRC has 20 multiyear research projects to address the current needs of the program and its customers. This update on NWRC research is structured around these program goals.

Denver Wildlife Research Center Closes

The former headquarters of WS' Denver Wildlife Research Center (DWRC) in Lakewood, CO, closed on August 4, 1997, when the remaining staff were transferred to Fort Collins, CO. All headquarters employees are now working at temporary locations in Fort Collins. A directory of NWRC headquarters and field station addresses and telephone numbers is provided on the inside front cover of this report. Plans are proceeding to complete the NWRC master plan on the Colorado State University (CSU) Foothills Campus. Construction of an office and laboratory building was begun in October 1997, with completion and occupancy expected in November 1998.

Developing Methods

Bird Research Projects

Title: Management Strategies To Control Blackbird Damage in the United States

Goal: Reduce the magnitude of health, safety, and nuisance problems caused by blackbirds and improve agricultural production by reducing blackbird depredation losses in citrus- and fruit-producing enterprises and on sprouting and ripening corn, sunflower, rice, and other grains.

Reducing Blackbird Damage to Sprouting Rice in Louisiana—Several species of blackbirds, particularly red-winged blackbirds, common grackles, and brown-headed cowbirds, congregate near Louisiana rice fields in winter roosts that may exceed 15 million birds. These birds cause extensive damage to sprouting and ripening rice with losses to rice growers estimated up to $ 11.5 million annually. Damage to sprouting rice can be locally severe with some growers reporting 100 percent loss. Repellants, such as anthraquinone (AQ) and methiocarb (Mesurol 75 percent wettable powder), were tested for repellancy in a series of cage and pen trials to identify treatment levels appropriate for possible field evaluations on newly seeded rice. In one series of tests, consistent, effective repellancy with no adverse effects on seed germination and growth was obtained when the compounds were applied to soaked rice seed at levels of 1.0 percent AQ and 0.1 percent methiocarb. In other cage tests with 1 percent AQ, blackbird consumption of treated rice seed was reduced an average of 92 percent over 3 days. In field evaluations conducted in Allen and Cameron parishes, LA, an AQ formulation significantly reduced sprout losses to birds in 2-ha treated plots compared to the results on control plots. Methiocarb results were less definitive due to low bird pressure at one site and heavy weed infestation at another. Samples of seeds and water from the study sites are being analyzed to determine chemical residues. Additional evaluations of these two repellants are planned for 1998.

Reducing Blackbird Damage to Sunflower Crops in the Northern Great Plains—Annually, about 25 million blackbirds migrate through the sunflower-growing areas of North Dakota, South Dakota, and Minnesota. Sunflower growers lose about $5 million worth of crops to these birds. Growers and government agencies are using nonlethal techniques to reduce blackbird damage. However, methods developed thus far have limitations of costs, logistics, and effectiveness.

Since 1993, NWRC scientists have studied the use of DRC–1339 for reducing the numbers of migrating blackbirds through South Dakota during March and April. Blackbirds prefer to feed in harvested cornfields near woodlots. Of the 32 species of birds visiting these fields, mallards, Canada geese, western meadowlarks, American tree sparrows, and killdeer were the most commonly observed nontarget species. The ring-necked pheasant and western meadowlark may be at the highest risk for acquiring an inadvertent lethal dose of DRC–1339 because of their feeding ecology and susceptibility to DRC–1339. Harvested soybean fields appeared to have less nontarget bird activity than harvested cornfields, suggesting that soybean fields may be better bait sites than cornfields for blackbirds. NWRC is conducting research designed to assess the effects of chronic sublethal doses of DRC–1339 on the production of viable eggs by ring-necked pheasants.

Title: Development of Management Strategies To Reduce Piscivorous Bird Predation at Aquaculture Facilities

Goal: Determine the magnitude of, and develop methodology to reduce bird predation on cultured aquaculture products, including catfish, baitfish, tropical fish, trout, and other finfishes.

Impact of Pelicans on the Southeastern Aquaculture Industry—American white pelicans that winter in the delta region of Mississippi, Louisiana, and the gulf coast breed in the north-central United States and Canada. A better understanding of the population status and migratory movements of these birds could lead to more effective strategies for managing depredations at southeastern aquaculture facilities. Thus, a biologist from the NWRC's Mississippi field station, in cooperation with the U.S. Fish and Wildlife Service (FWS), reestablished a pelican banding program at Chase Lake National Wildlife Refuge in North Dakota. This lake contains the largest breeding colony of American white pelicans in North America. Personnel from the North Dakota Wildlife Services State office, U.S. National Biological Service, St. Cloud State University, and North Dakota State University assisted with this banding project. NWRC biologists will continue to monitor breeding and wintering pelican populations and will capture pelicans for satellite and VHF transmitter tracking studies.

Wading Bird Predation at Tropical Aquaculture Facilities in Central Florida—NWRC biologists documented losses due to bird predation at 10 pairs of ponds located at 5 aquaculture facilities during 1996. Losses in ponds from which birds were excluded with netting ranged from 2 percent to 23 percent, whereas losses in unprotected ponds ranged from 14 percent to 82 percent. Estimated monetary losses were as high as $3,600/pond. It appears that netting ponds to control bird depredations is economically feasible, particularly with high-value fish.

Wading bird populations varied among sites, but the snowy egret, green heron, tricolored heron, and little blue heron were the principal depredating species. Field observations revealed feeding rates by little blue herons as high as 4 fish/minute. In an evaluation of methyl anthranilate (MA), a potential bird repellant, captive great egrets were not deterred from taking fish from wading pools treated with MA. The treatments did, however, cause a substantial increase in the time birds handled the fish before eating them.

Title: Management of Wildlife That Pose Hazards to Aviation

Goal: Develop safe and effective methods for reducing wildlife hazards to the air transport industry

Management and Analysis of FAA National Data Base on Bird and Other Wildlife Strikes With Aircraft, USA—Bird and other wildlife strikes to aircraft are serious economic and safety problems for civilian aircraft in the United States. Pilots and others report bird strikes to the Federal Aviation Administration (FAA) using FAA Form 5200–7. However, until now this information has not been entered into a computerized data base so that the wildlife strike problems can be measured and analyzed. Through an interagency agreement with the FAA, NWRC took over management of the FAA wildlife-strike reporting system in 1995. Biologists now have more than 17,000 strike reports from 1989 through 1997 edited and accurately entered into the National Wildlife Strike Database. This data base is already proving to be invaluable in providing biologists, aeronautical engineers, and airport managers with specific information on strike histories for airports, aircraft and engine types, and regions of the United States. The data base allows biologists and engineers to better define problems by species, time of year, and other factors so that science-based management and preventative plans can be developed, justified, and evaluated. NWRC personnel have already handled more than 140 requests for information on bird strikes nationwide by biologists, engineers, and aviation analysts. As more strike data are entered, the data base will become an even more powerful management, research, and evaluation tool.

As part of this data-base entry process, NWRC biologists, in cooperation with the FAA, recently completed the first multiyear analysis of reported wildlife strikes to civilian aircraft for the United States. Between 1993 and 1995, on average 2,200 strikes to civilian aircraft were reported per year. Gulls (30 percent) and waterfowl (13 percent) were the most commonly struck species groups. Mammal strikes included 123 deer and 24 coyotes. It is estimated that fewer than 20 percent of known strikes were reported to the FAA, indicating that the nationwide economic losses from strikes to civilian aircraft in 1993–1995 exceeded $150 million/year. Other researchers have estimated losses from strikes to U.S. military aircraft to average $112 million/year. Thus, bird and other wildlife strikes are estimated to cost the U.S. military and civilian air transport industry more than $260 million/year.

Aerial Photography Accurately Monitors Gull Population During Experimental Management Program at Kennedy International Airport—The collision of birds with aircraft is a serious problem at John F. Kennedy International Airport (JFKIA), New York. Laughing gulls accounted for 52 percent of the bird strikes (an aircraft striking >1 bird) between 1988 and 1990, and the average number of strikes per year was 157. This species is present from May through September in association with a 7,600-nest colony (1990) in Jamaica Bay adjacent to the airport.

An experimental program to reduce gull collisions with aircraft was undertaken between May and August annually from 1991 to 1996. In this control program, WS biologists are stationed on airport boundaries and use shotguns to shoot gulls flying over the airport. No nontarget species have been affected, and no nontarget gulls (i.e., gulls not on the airport) were killed. This program has had a dramatic effect on bird strikes. The number of aircraft striking laughing gulls during the shooting period declined by 66 percent in 1991 and 76–89 percent in 1992–96, compared with an average of 136 strikes during the same months for 1988–90. Strikes by other gull species were reduced by comparable amounts.

Aerial photography was used to monitor the effect that the shooting program had on the nearby laughing gull colony. Ground-truth plots indicated that nest counts from photographs were accurate within

5 percent of the actual population. Censuses indicated that the nesting population declined by only 38 percent from 1990 to1996 (7,629 to 4,730 nests). In addition, North American Breeding Bird Survey data indicated that the laughing gull population along the Atlantic Coast has remained stable since 1991. Thus, although shooting is an effective means of reducing the incidence of bird strikes, the program has not caused a major decline in the nearby nesting colony nor the U.S. population.

The recommended long-term solution is to relocate the nesting colony away from JFKIA. A seasonal shooting program, coupled with other management programs to deter gulls from the airport, should continue to minimize the number of gull–aircraft collisions until this relocation is achieved.

Forward Looking Infrared System for Detecting Deer on Airports at Night—The United States' white-tailed deer population is at an all-time high of more than 25 million animals. Deer have adapted to suburban and agricultural habitats, creating numerous problems including collisions with arriving and departing aircraft at airports. A recent NWRC report documented more than 250 civil aircraft collisions with deer in the United States since 1983, most of which resulted in serious damage to the aircraft.

Detection of deer on airport property at night is critical to allow timely hazing from runways and to develop, justify, and evaluate deer management plans. At the request of the FAA, NWRC biologists compared the effectiveness of Forward Looking Infrared Radar (FLIR) systems, spotlighting, and night vision to detect deer at night. Surveys were conducted for 12 consecutive nights during January 1997 along a 10-km route on the National Aeronautic and Space Administration's Plum Brook Station, Erie County, OH. Biologists observed 825 deer with FLIR, 716 with spotlight, and only 243 with night vision. In addition, 61 other mammals, primarily raccoons and cottontail rabbits, were observed with FLIR, 28 with spotlight, and 7 with night vision.

This study indicates the FLIR system is the most effective means for nocturnal detection of deer at airports. In addition, FLIR, in contrast to spotlighting, has the advantage of being unobtrusive. This characteristic should also make FLIR an ideal monitoring aid for suburban deer populations.

Title: Development of Nonlethal Chemical Repellants for Birds

Goals: Develop methodologies that contribute toward the discovery and practical development of nonlethal, environmentally benign chemical repellants for use in resolving conflicts between wildlife and agriculture and industry.

Chemical Area Repellants—Effective nonlethal chemical repellants have been developed to protect commodities from being eaten by birds. However, these repellants require direct application onto the surface of the resource to be protected, and birds must sample the material before they are repelled. This sampling leads to crop damage, and if the bird population is large enough, the economic cost of the sampling behavior alone is unacceptably high. NWRC is testing the feasibility that nonlethal chemical repellants can be used as area repellants. Previous studies have shown that primary repellants work on the principle of irritation. Therefore, formulations and an aerosol delivery system that target sensitive receptor systems in birds are promising because they do not affect humans and other mammals. In addition to protecting agricultural crops, this strategy may prove useful in keeping birds away from toxic waste sites, where any landing at the site may prove harmful to the bird.

NWRC studies have shown that MA, currently registered as a bird repellant, can be applied to the surface of aquaculture ponds without harming the fish. Laboratory studies have shown how birds react to aerosols of MA. NWRC scientists are evaluating the use of field delivery systems, radar detection, and triggering systems for their efficacy at protecting the air space over large areas (20–480 ha). If this research proves successful, the strategies of repelling birds during critical periods or over sensitive areas will be dramatically changed.

Title: Management Strategies To Reduce Bird Problems in the Western United States

Goal: Develop safe and effective methods to reduce bird problems in the Western United States.

Impacts of Canada Goose Movement on Aircraft at Elmendorf Air Force Base, Anchorage, AK—On September 22, 1995, at Elmendorf Air Force Base (EAFB), an E–3 Sentry Airborne Warning and Control System (AWACS) aircraft ingested several Canada geese on takeoff and crashed, killing 24 people. In response to the crash, researchers captured and radio-collared 74 Canada geese at several sites around Anchorage, AK, to identify flocks that frequent EAFB; ascertain local movements, flock cohesion, and postmolt dispersal; and evaluate the effectiveness of hazing at the base. Telemetry data and visual observations of radio-collared geese indicated the majority (55 percent) of geese observed at EAFB were from nesting sites within 10 km of the airbase. One hundred twenty-one marked geese from 14 capture locations were observed once on EAFB. Of geese observed >2 times on EAFB, 63 percent were captured within a 10-km radius. A significant relationship ($P = 0.0076$) was found between the proportion of geese invading the base and the distance captured from it. Geese established primary movement patterns soon after molt and typically maintained those patterns until migration. Intensive hazing kept geese out of an exclusion zone surrounding the runways on EAFB and prevented the majority (67 percent) of geese from returning. However, hazed geese dispersed on average, only 3.5 km from the exclusion zone. Marked geese were most mobile during afternoon hours between noon and 6 p.m. These data have been used to define goose populations that can be a threat to aircraft safety and develop a Canada goose management plan for EAFB and the Anchorage area.

Mesurol® and ReJexit AG–145® Show Promise in Reducing Horned Lark Damage to Lettuce Seedlings—Sprouting lettuce crop losses to birds, especially horned larks, cost growers millions of dollars annually. NWRC researchers conducted a series of aviary and field tests to evaluate the repellancy of Mesurol, ReJexit AG–145 (methyl anthranilate), lime, activated charcoal, and fipronil. In aviary tests, Mesurol and AG–145 significantly reduced consumption of lettuce seedlings by horned larks. Seedlings showed no phytotoxic effects from the compounds. However, in field tests, horned lark damage to lettuce seedlings in treated plots was virtually unchanged from damage to control plots during the test period. Test plots were probably too small to reflect field damage, and further testing is planned.

Corn Oil Reduces Hatching Success of Ring-Billed Gulls—Ring-billed gulls nesting in large island colonies on the Columbia River have been implicated in depredations on migrating salmon smolt. One such colony has more than 7,000 breeding gulls with the potential to increase to 14,000 birds postbreeding. In 1995, NWRC biologists, in cooperation with Washington State WS personnel, began a 3-year study to determine the impact of ring-billed gulls on Columbia River salmon smolt and develop management techniques. Egg oiling—spraying egg shells with oil to prevent chick development—has been identified as a potential gull population management method. Laboratory and field studies have shown that corn oil use reduces hatching success by as

much as 99 percent. Data further suggest that prolonged use could reduce the number of returning adults.

Modifying Ground Covers on Airfields To Reduce the Risk of Bird Strikes—Populations of Canada geese have expanded in all flyways, and especially in urban–suburban environments. These populations are implicated in causing depredation, increasing insurance rates, and creating health and safety problems in these environments. Canada geese are generally attracted to airfields because they provide large, open spaces and a variety of preferred foliage. To reduce this attraction, NWRC researchers evaluated Canada goose preferences for vegetation types not normally planted at airfields. At EAFB, Canada goose preference for Kentucky bluegrass, bluejoint reedgrass, beach wildrye, Bering hairgrass, lupine, dandelions, and flightline turf (brome, dock, and red fescue) was compared in pen tests. Canada geese preferred dandelions and flightline turf over Kentucky bluegrass. Lupine, bluejoint reedgrass, and beach wildrye were significantly less preferred than Kentucky bluegrass and beach wildrye was least preferred. Implementation of a habitat-management plan based on these kinds of vegetation data could offer a long-term solution by reducing goose visits and the need for control.

Mammal Research

Title: Control of Rodent Damage to Hawaiian Agricultural Crops

Goal: Develop safer and more effective methods for reducing rat damage to Hawaiian agricultural crops.

Nonlethal Predator Odors for Reducing Rat Damage to Agricultural Crops—Rats cause significant economic, human health, and ecological problems in Hawaii. At present, few methods of rodent control offer satisfactory relief. Hawaiian sugarcane growers introduced mongooses into Hawaii in the 1870's in an unsuccessful attempt to reduce rat populations in sugarcane fields. Though predation by mongooses did not result in reduced rat populations, these predators subsisted on a diet composed largely of rats in many areas. Chemical repellants derived from predators might offer more effective and longer lasting protection from vertebrate depredations compared to current damage control measures.

A field study conducted at the NWRC Hawaii field station indicated that rats avoid traps soiled by mongooses. As a result of this finding, NWRC scientists conducted followup laboratory and field studies to evaluate the repellancy of mongoose feces and urine to black rats and Polynesian rats. Captive wild rats were exposed to water, butyric acid, mongoose feces, or mongoose urine in a 150- $\times$ 60- $\times$ 120-cm partitioned arena, and their behaviors were recorded with a video camera. Neither the mongoose feces nor urine had any apparent effect on rat behavior. During the field test, 50 pairs of live traps were set and monitored along each of 12 transects in forested areas and adjacent to recently harvested sugarcane fields. One trap in each pair was randomly selected for application of mongoose feces or urine. Significantly fewer rats were captured in traps soiled with mongoose feces than traps soiled with mongoose urine or unsoiled traps. The discrepancy between the laboratory and field results indicates that researchers should incorporate relevant factors in the natural environment into their test paradigms and cautiously interpret the results of laboratory tests with captive animals. Additional research is warranted to determine the active compound(s) in mongoose feces that repel rats and explore the use of such compounds to reduce rat damage to agricultural crops.

Economic Thresholds for Controlling Rat Damage to Macadamia Nuts—Rats are known to damage at least 5–10 percent of the developing macadamia nut crop each year in Hawaii. An important fact that was not well documented is the impact of this on macadamia nut yields. Scientists at NWRC's Hawaii field station evaluated the effects of simulated damage on

yields of mature nuts at two locations on the island of Hawaii. Damage was simulated by removing 10 percent or 30 percent of the developing nut clusters from trees at 90, 120, or 150 days after flowering. At harvest (210–215 days after flowering) number, weight, and maturity of harvested nuts was determined. Removal of 10 percent of the crop load had no measurable effect on yields of mature nuts, regardless of when damage was inflicted. Yields of trees with 30 percent of nut clusters removed differed from control trees (no nut clusters removed) only when damage was inflicted at 150 days after flowering. These results raise questions about the cost effectiveness of current rodent control programs, especially during early nut development. Growers may be able to tolerate damage to 10 percent of their developing nuts without suffering economic losses and may be able to sustain losses as high at 30 percent, provided that damage is incurred before 150 days after flowering. However, high rat populations and damage prior to this time, although having minimal impact on yields, might indicate the need to apply measures to reduce damage later in the crop cycle.

Improving Methods for Applying Rodenticides in Macadamia Orchards—Macadamia growers in Hawaii try to control rat populations in their orchards mainly by broadcasting rodenticides on the orchard floor. However, because recent studies indicate that rats in macadamia orchards spend little time on the ground, ground application of rodenticides may be ineffective. To determine the optimum location for placing rodenticide baits in orchards, NWRC scientists evaluated consumption by rats of nontoxic oats that had been placed in various locations in orchards. The oats had been treated with tetracycline hydrochloride, an antibiotic that chelates with calcium in growing bones and teeth and fluoresces under W light. Approximately 10–14 days after placing the bait in the orchard, field crews captured rats and examined them for evidence of feeding. The greatest percentage of marked rats was consistently captured in orchards where the bait had been placed in trees, and the lowest percentage was captured in orchards where the bait had been broadcast on the ground. Bait acceptance was intermediate where the bait had been placed in burrows. These results suggest that placing baits in trees will target rats that not only are more likely to eat poison but are also more likely to damage developing nuts.

Development of Cost-Effective Methods To Control Rats in Hawaiian Native Habitat—A graduate student, in conjunction with scientists at NWRC's Hawaii field station, is conducting a graduate research project to develop a practical, cost-effective method for applying rodenticides to reduce rat populations in native Hawaiian forests. Rats were introduced to the Hawaiian islands first in association with early Polynesian and later Western explorers. This introduction has had a devastating impact on native ecosystems. Hawaii suffers some of the highest extinction rates of native fauna and flora in the world; predation and competition from introduced rats have contributed significantly to this ecological devastation. Application of rodenticides is the most cost-effective method of reducing troublesome rodent populations. However, current methods for applying rodenticides in native Hawaiian habitats

require the use of bait stations and thus are labor intensive and impractical for use over large areas. Broadcasting rodenticides by hand or from airplanes would facilitate controlling rodent populations over large expanses. Research to evaluate the minimum exposure time and dosage of the rodenticide necessary to kill rats is complete. Field evaluation with nontoxic bait markers to determine rat feeding locations is being undertaken. The results will provide a basis for developing more cost-effective methods to control rats in Hawaiian native habitats.

Title: Integrated Pest Management Strategies for Rodent Damage to Crops and Rangeland

Goal: Incorporate effective nonlethal methods into new or existing IPM approaches that limit invasion and reinvasion and reduce damage by small mammals to susceptible crops; and develop computer-assisted economic models for demonstrating appropriate management strategies.

Prairie Dogs and Crops—Prairie dogs are estimated to cause $10 million in damage to crops and forage annually in Colorado alone. NWRC scientists are cooperating with CSU investigators to research innovative, nonlethal methods useful for reducing the negative impacts of prairie dogs on agricultural habitats.

Reproductive inhibition is a promising control method that may limit the growth and expansion of prairie dog colonies. However, disrupting the reproductive physiology of small-mammal populations to limit their growth may also disrupt normal behavior of individual prairie dogs or family groups (coteries) within an established colony. To a large extent, behavioral changes will determine the success or failure of reproductive inhibition methods such as chemosterilants, synthetic hormones, and immunocontraceptives, all of which interrupt normal reproductive physiology. Thus, it is important to be able to predict the impact that reductions in reproduction or hormone levels will have on prairie dog behavior.

NWRC and CSU scientists have begun to evaluate the social behavior of black-tailed prairie dogs reproductively inhibited by surgical sterilization. The investigators are determining dispersal, immigration and reproductive success—all important factors in the expansion of colonies—by trapping and releasing individually marked prairie dogs. The subsequent behavior of coteries with sterilized males is being compared to that of coteries with intact males. Prairie dogs are good candidates for reproductive management. Because they defend territories, limited invasion helps to maintain artificially lowered population levels. Colony expansion through emigration should be considerably lower since young animals that disperse are not being added. The results of this study will provide the behavioral data to guide researchers in developing new management techniques relying on reproductive inhibition.

Title: Management of Livestock Depredation: Developing More Selective Control Strategies

Goal: Develop effective and environmentally responsible strategies for reducing livestock depredation through selective targeting of predators.

Efficacy of Selective Coyote Removal—Research findings at the University of California (UC), Hopland Research and Extension Center (HREC) indicate that the selective removal of a relatively few sheep-killing coyotes will be more effective at reducing depredation losses than the nonselective removal of part of the local coyote population in the vicinity of a livestock operation. Research is underway to determine the space-use patterns of radio-collared coyotes and classify them as territorial breeders, transients, or territorial associates. Sheep-killing coyotes are then identified by matching their locations and the time and place of sheep kills, or by their death as a result of attacking a sheep wearing a Livestock Protection Collar (LPC) containing Compound 1080 (sodium monofluoroacetate).

The pattern of sheep depredation has been shown not to be random but rather is clustered over days or weeks in the same pasture or territory. Selective removal of coyotes associated with kill-clusters has now been documented in nine cases: seven involving territorial breeders, one involving a coyote of unknown status, and one involving a transient coyote. In each case, depredation stopped in that area following the removal of the coyote. Time to resumption of killing varied from 2 to 7 months. In one case, a territorial breeding male was removed following 30 kills in his territory during the preceding 3 months. During the subsequent 3 months, an additional three kills were found, evidently by his mate, who was provisioning pups. Following her removal, there were no further kills over the next 5 months. In another example, a territorial breeding male was removed following 11 kills during the preceding 3 months. No further kills occurred in his territory for 3 months.

Selective coyote removal was initiated on the UC–HREC in the fall of 1996. This strategy was evaluated during the 1997 lambing season and will be evaluated again during the 1998 season. Concurrently, the 1080 LPC is being used as a method for selective removal. Results from 1997 are encouraging. Both the numbers of confirmed coyote-killed sheep and missing lambs were substantially lower in 1997 than in each of the preceding 3 years when search efforts for dead sheep were comparable. However, the interpretation of this result is confounded by there having been substantially fewer lambs available to coyotes in 1997.

Replacement of Territorial Coyotes Removed for Killing Sheep—Territorial, breeding adults were responsible for the majority of coyote depredations on domestic sheep in a study in north-coastal California. This fact indicated that selective removal may be more effective than local population reduction as a control strategy. Removal on the relatively small scale of an individual ranch or livestock operation is likely to have a short-term effect on reducing depredation due to replacement by surplus, nonterritorial coyotes from the surrounding area. A UC–Berkeley graduate student working in cooperation with NWRC biologists, examined the coyote replacement process following a period of intensive control on the HREC, focusing on the lag times until breeding territories were reestablished and sheep depredations resumed. The control effort resulted in the removal of 34 coyotes on this 5,600-acre sheep research facility between the fall of 1994 and the fall of 1995, including 3 of 4 known breeding pairs and 10 of 11 radio-collared study animals. Research trapping resumed following the cessation of operational control in November 1995 with 25 new animals collared. By March 1996, the territorial vacancies had been filled, with four new coyotes replacing the original three, and at least two of them producing pups. Three of the coyotes had access to lambs, and lamb depredations occurred in all three territories. Depredations during the 1996 lambing season were high.

The implications of this result to management are twofold. First, the benefit of coyote removal at this spatial scale is probably for a period of less than 6 months. Second, for removal to be effective, it must occur before the annual peak in depredation, which is usually the lambing season. At the HREC, territorial breeding adults were more easily removed after the lambing season (December–April) than when coyotes were provisioning pups (April–August).

Evaluating Bobcat Predation on Lambs in North-Coastal California—Historically, annual numbers of missing lambs have been higher (10–12 percent of pastured lambs) than the numbers of confirmed predator-killed lambs (3–4 percent) on the HREC. The problem of missing lambs is not unique to the HREC. Bobcats occur at high densities in this region of north-coastal California, warranting suspicion that they may be responsible for the missing lambs. Lamb kills for which the predator species is determined are most commonly attributed to coyotes and rarely to bobcats. The role of bobcats in the high numbers of missing lambs was investigated by an NWRC-sponsored UC–Berkeley graduate student, who examined the occurrence of sheep remains in bobcat versus coyote scats, the fate of radio-collared lambs, and bobcat use of space with respect to lambs.

Lamb losses during this study were similar to historical levels, and included 64 confirmed predator kills (5 percent of the number of lambs pastured) and 134 (11 percent) missing. The proportion of 259 bobcat scats containing wool was small (4 percent). Also, occurrence did not peak in the lambing season, suggesting that any sheep consumed by bobcats was scavenged. A higher proportion of 467 coyote scats contained wool (21 percent), and wool discoveries peaked during the spring.

Four pastures with 119 small lambs were closely monitored for predation for 30 days each. These were pastures with traditionally high numbers of missing lambs. A total of six lambs were predated (5 percent), and two were missing (1 percent) and never recovered. Four of the six kills were determined to be due to coyotes, but the cause of death of the other two could not be identified. Nine of 10 radio-collared bobcats monitored were in the general vicinity of pastures with lambs.

Researchers concluded from this study that bobcats are not important predators of lambs at HREC and probably have not been responsible for the large number of missing lambs in past years. Wild prey may provide a stable buffer to predation on lambs by bobcats.

Title: Ecology of Coyote Depredation

Goal: Determine interrelationships between depredation on livestock and the abundance and behavior of predators and natural prey.

Population Ecology of Coyotes and Spatial Interactions With Swift Foxes on the Piñon Canyon Maneuver Site, Colorado—An NWRC scientist and three graduate students funded by the Berryman Institute at Utah State University, the U.S. Army, and the FWS initiated studies to develop accurate swift fox survey methods and to evaluate interactions between swift fox and coyotes in Piñon Canyon, CO. Since field work began in February 1997, crews have radio-collared 34 foxes and 16 coyotes. More than 800 telemetry locations for foxes and 300 telemetry locations for coyotes have been collected, and more than 100 swift fox dens have been identified. These data are being used to determine pack sizes for coyotes and space use for both species. Two radio-collared foxes that had been killed by coyotes have been recovered. To evaluate food habits, researchers are collecting coyote and fox scats. Field work will continue for the next 2 years.

Coyote Depredation Control: an Interface Between Biology and Management—NWRC scientists recently reviewed the available literature regarding the efficacy of coyote management programs,

the relative effectiveness of various control measures, and the influence of coyote management programs on coyote demographics. The principal conclusion of this review is that depredation can place livestock producers in economic jeopardy. Various techniques and procedures can prevent or curtail predation on livestock, but none is universally effective.

Techniques used in preventative depredation-control programs usually do not entail removing coyotes and typically involve producer activities; removing coyotes to solve depredation problems is usually done by agency personnel. Unfortunately, dominant territorial animals most likely to cause depredations are also the most difficult to remove. Differences among depredations, the circumstances in which they occur, and the behaviors and motivations among coyotes make simple resolution of problems unlikely.

Successful depredation management requires a variety of techniques and procedures and an integrated program to select and apply the appropriate tactics. Preferred options should be those that resolve problems efficiently in the least intrusive manner. This requires a careful analysis of each situation that matches biological, legal, social, and economic considerations with an understanding of the merits and limitations of individual techniques.

Title: Analysis of Taste and Olfaction in Selected Wildlife Species

Goal: Apply the methodology and findings from basic multidisciplinary chemosensory research to the development of new methods for controlling wildlife damage.

Sensory and Perceptual Mechanism of Attractants and Repellants—NWRC scientists at the Monell Chemical Senses Center seek to understand the sensory and perceptual mechanisms that underlie attraction and repulsion in mammals and birds. This understanding is then used to develop new tools and strategies that minimize crop damage, reduce hazards to wildlife that result from agricultural and industrial practices, and improve the effectiveness of products currently used for wildlife damage management. For mammals, formulations have been developed that attract deer for the delivery of sterilants and Lyme disease vaccines. Research also is focused on identifying nontoxic rodent repellents to prevent damage to crops, buildings, and equipment. A source of such repellants is the chemical defenses produced by plants against insect and vertebrate herbivores. Finally, a variety of investigations is aimed at chemical interactions between predators and prey. Substances such as predator urine, feces, and glandular scents provide potential prey with information about the predator and typically cause avoidance. For birds, molecular modelling techniques help to develop new chemical repellants. Ongoing studies are evaluating repellent formulations to minimize depredation by fish-eating birds at aquaculture facilities.

Siberian Pine-Needle Oil Repels Rodents But Not Birds—Ecologically safe and effective repellants are needed for the management of birds and rodents. A source of such repellants is plant secondary defense compounds that defend against herbivores. These materials are especially attractive given the recent decision by the U.S. Environmental Protection Agency (EPA) to permit the use of some natural products without extensive registration testing. To determine the effectiveness of Siberian pine as a general vertebrate repellant, NWRC scientists at the Monell Chemical Senses Center examined the responsiveness of deer mice, prairie voles and European starlings to adulterated feed. Both rodent species avoided this terpenoid mixture in two-choice tests, but repellancy diminished significantly when alternatives foods were unavailable. Starlings failed to avoid pine-needle oil regardless of the testing paradigm. These findings suggest that pine-needle oil may have promise as a rodent damage control agent in settings where the use of a nonlethal product is desirable and alternative food sources are readily available.

Title: Reproductive Intervention Strategies for Managing Coyote Predation

Goal: Determine whether sheep losses to predation can be reduced by sterilizing coyotes on territories where sheep and other livestock are pastured. Determine if sterilization is a viable method of reducing coyote densities. Develop and transfer information critical to the registration and/or practical application of sterilant technologies and pharmaceutical products.

Coyote Sterilization as a Method of Reducing Depredations of Domestic Sheep on Lambing Ranges—In 1983, DWRC scientists showed that predation on domestic sheep by adult coyotes stopped when their pups were removed. When both adult and pup coyotes were removed, the number of sheep killed declined by 99 percent. When only pups were removed (and the adults were allowed to remain), sheep losses declined by 92 percent. These observations led to the hypothesis that sterilizing territorial coyotes might be an effective method for depredation control.

For several reasons, sterilization could be more effective than removing the pups of depredating adults. First, no sheep losses would have to occur before the pups were removed. Second, sterilized coyotes could defend their territory against other coyotes that might kill sheep. Third, sterilization could have long-term effects because pair bonds between coyotes are long-lasting and coyotes are long-lived. Implicit in these theoretical benefits, are the untested assumptions that (1) sterilized resident coyotes maintain their territories to the exclusion of intact coyotes, (2) prohibiting coyotes from having pups affects depredation on sheep the same way as removing pups, and (3) compensatory mechanisms within the population resulting from a segment of the population being sterilized do not alter the population's social systems or demographics in ways that would increase depredation.

An NWRC scientist and a Utah State University graduate student have initiated a field study to test these assumptions. Deseret Land & Livestock Company, a major ranch and sport-hunting business in northern Utah, has provided the study site and logistical support, and Utah State's Agricultural Experiment Station has provided a herd of sheep. To date, a number of coyotes from the 10–12 packs on Deseret Ranch have been radio-collared, and territorial boundaries are being mapped. Depredations by intact radio-collared animals also are being recorded. Subsequently, collared animals will be recaptured, surgically sterilized, and released. The behavior of animals before and after sterilization will be compared to evaluate whether depredation is reduced following surgery. The research is expected to involve 3 years of field work.

Reproductive Control in Coyotes Using Hormone Agonists—NWRC scientists and a graduate student from the University of Wyoming evaluated whether an analog of the French abortion drug RU–486 could be used to terminate pregnancies in coyotes. Female coyotes in kennels were bred and pregnancies were determined by ultrasound techniques. Oral administration of the analog reliably caused abortion of the conceptus. However, there were individual differences in responsiveness to the drug probably related to differences in the timing of drug delivery. A practical implication is that RU–486 analogs can negatively (albeit reversibly) influence coyote reproductive fitness, provided that drug doses are consumed at times when the female is vulnerable to the drug.

Title: Sensory and Behavioral Methods for Managing Predation on Livestock

Goal: Identify chemical repellants and deterrent methods and create attractive baits for target-specific delivery of pharmaceutical substances to reduce livestock depredation.

Contrasting Colors Attract Coyotes—NWRC scientists have determined that visual cues that contrast with background soil and vegetation are attractive to coyotes. M–44's fitted with colored tops that contrasted with the background were significantly more likely to be activated by coyotes than M–44's with colored tops that blended with the background. In addition, at test sites in the Eastern United States, raccoons were as likely as coyotes to activate M–44's. Tooth marks suggested that many of these pulls were by mouth, and the number of mouth pulls increased when the M–44 was mounted horizontally (e.g., against a tree) than vertically (e.g., placed in the ground). Overall, these results suggest possible methods of increasing M–44 effectiveness, and the possibility that M–44's might be used to deliver chemicals (e.g., vaccines) to species other than coyotes. The fact that color increased detection and attractiveness also has important implications for developing methods to increase consumption of rabies vaccine baits by coyotes.

Llamas Effectively Deter Coyote Predation on Sheep—Anecdotal information has suggested that llamas effectively guard herds of domestic sheep against predation from coyotes, but no controlled studies have been conducted. A study recently completed by NWRC scientists and graduate students at Utah State University provided gelded male llamas to 21 sheep producers that graze sheep within 20- to 800-ha fenced pastures. (Gelded males were used rather than females or intact males because gelded males are relatively less expensive and do not attempt to mate with sheep.) During the first year of the study, all producers who received llamas were favorably impressed with the way llamas interacted with the sheep, and several witnessed llamas chasing domestic dogs, red foxes, or coyotes. Of 21 producers with llamas, 19 (90 percent) reported fewer sheep lost to coyotes in 1996 than the previous year, while only 4 of 10 producers (40 percent) without llamas (controls) reported fewer losses for the same period. Producers with guard llamas lost an average of 6 lambs to predators during the first year of the study compared to an average loss of 17 lambs for control producers. Many of the producers volunteered an interest in purchasing their experimental llamas at the end of the study.

Title: Reducing Mammal Damage to Forest Resources

Goal: Provide feasible and effective methods for reducing wildlife damage to forest resources.

Response of Nontarget Species to Underground Strychnine Baiting for Pocket Gopher Control in Reforested Areas—Pocket gopher damage to newly planted seedlings and saplings is a major problem to reforestation efforts in the Pacific Northwest. Pocket gophers feed on stems, roots, needles, and terminal buds of seedlings and saplings of most conifer species. Strychnine baiting to reduce pocket gopher populations is one of the few feasible methods available to protect forest resources. Baits are placed below ground in gopher burrows to reduce negative impacts on nontarget species. Primary and potential secondary hazards, however, may still be present. A trap and release program was implemented to assess the immediate risk and the long-term effects of baiting on nontarget small mammals. The only species present in sufficient numbers to adequately assess population changes were golden mantled ground squirrels and yellow pine chipmunks. Trapping was conducted once prior to baiting and then for 6 weeks after baiting at 2-week intervals. Trapping was repeated the next spring, shortly after snowmelt, and then again 1 year after the pretreatment and the first posttreatment trapping periods.

Strychnine applications reduced pocket gophers to less than 10 percent of the pretreatment population. Ground squirrel numbers declined immediately after baiting in treated areas compared to control areas. Several ground squirrel carcasses found above ground had strychnine bait in their cheek pouches, indicating that these individuals had access to the strychnine baits. Although a few chipmunk carcasses were also discovered, aboveground chipmunk populations were not negatively affected by the strychnine treatment. Because few predators or scavengers were encountered during the study, it was impossible to accurately assess possible secondary hazards. Prior work and observations, however, suggest that small-mammal carcasses are largely consumed by insects within 48 hours.

Nonlethal Damage Control Methods for Pocket Gophers—Data analyses continued for studies conducted at NWRC's former field station at Bend, OR, on nonlethal approaches for reducing damage to seedlings by pocket gophers. These previous studies provided long-term data on seedling survival and gopher activity. Analyses of data from a study using the herbicide 2,4–D to reduce pocket gopher forage showed that use of this herbicide resulted in substantial reductions in gopher damage rates and greatly increased seedling survival rates. Another data analysis demonstrated that after 6 growing seasons, Vexar® plastic mesh tubes protected seedlings from gopher damage, greatly reduced mortality, and possibly created a microclimate that enhanced seedling growth.

Title: Reducing Beaver Damage to Agricultural Resources

Goal: Develop feasible and effective methods for reducing beaver damage to agricultural resources.

Inwater Electroshocking Devices To Repel Beaver—A pilot study was conducted at Fort Riley, KS, during 1996 with inwater electroshocking devices designed to repel beaver. These patented devices, developed at the NWRC, operate by generating an electrical field in water when the presence of a beaver is detected by an infrared sensor. Unlike conventional livestock electroshocking equipment, the electrical shock is delivered through the water in which the beaver is swimming, so that it is not necessary for the animal to make direct contact with a metal electrode or fence. Once the equipment is activated, the only escape for a beaver is to swim out of the electrified volume of water. The level of the electrical shock is maintained at a sufficiently low intensity and short duration to ensure that the devices are nonlethal to the beaver.

Field tests of these electroshocking devices were conducted by WS personnel from Kansas and a student from Lincoln University following training by NWRC electronics personnel. Results indicated that these battery-powered, inwater electroshocking devices successfully repel beaver. Videotapes show beaver swimming along the edge of the electrified volume of water but not entering the range of the electroshocking device. An electrical circuit has been incorporated in the device to trigger a secondary device that emits a lingering odor or taste as a cue for the animals to avoid an area. These initial studies also suggest that the addition of this second stimulus may cause beaver to be less likely to reinvade areas after the electroshocking devices are removed or disabled.

Title: Reducing Bear Damage to Agricultural Resources

Goal: Provide feasible and effective methods for reducing bear damage to agricultural resources.

Chemically Mediated Foraging Preference of Free-Ranging Black Bears—Two approaches were used to assess the role of chemical constituents in food choices made by black bears. In the first study, vascular tissue samples were collected from Douglas-fir trees recently damaged by black bears. Samples were extracted and analyzed by liquid and gas chromatography to determine carbohydrate and terpenoid concentrations. Multiple-regression models indicated that these chemical constituents may be important factors affecting forage selection by black bears. A subsequent field bioassay supported this model for bear selection criteria. Free-ranging bears preferred low-terpenoid diets to high-terpenoid diets at the high carbohydrate concentration. Bears also preferred the high-carbohydrate–high-terpenoid diet to the low-carbohydrate–high-terpenoid diet.

Foraging preferences arise from the interplay between taste and feedback. Macronutrients such as the sweet-tasting carbohydrates produce positive feedback while toxins such as terpenoids produce negative feedback. Though some terpenoids can be acutely toxic, mammals have evolved means to circumvent toxicosis through detoxification. The detoxification processes of absorption, biotransformation, and elimination are energy consuming and the tolerance of diets high in secondary metabolites depends on the rate of nutrient absorption. Thus, bear preference for vascular tissue with higher carbohydrate concentrations can be expected as long as the nutritive benefits exceed the cost of terpenoid detoxification.

Silvicultural Impacts on Terpenoid Defenses in Douglas-fir Vascular Tissue—The effect of two common silvicultural practices on growth and terpenoid production in Douglas-fir vascular tissue was assessed. Thinning had significant impact on tree diameter (measurement of cumulative growth) as well as vascular tissue density (measurement of current growth). The vascular tissue terpenoid concentration, however, did not decrease in response to increased investment in growth. Decreases in the concentration of a few individual terpenes did not result in statistically significant decreases in total terpenoid content because the concentration of alpha-pinene was not affected. This is consistent with previous work which demonstrated that the loblolly pine phloem levels of alpha-pinene, beta-pinene, myrcene, and limonene were not affected by thinning. These results indicate an overall increase in the production of constitutive terpenoid defenses directly proportional to increased growth.

The effects due to thinning were observed regardless of the time elapsed since treatment. The areas sampled in this study had all received thinning treatments between 4 and 9 years prior to sampling. Previous studies with Douglas-fir have demonstrated that increased individual tree growth resulting from thinning can be observed in as little as 2–3 years following treatment depending on age, site quality, and intensity of thinning.

Fertilization increased tree diameter but did not impact vascular tissue density. This result reflects the cumulative nature of fertilization effects on growth. Investigation of elapsed time since fertilization and number of fertilization treatments demonstrated that repeated treatments were required to maintain the treatment effect on diameter at breast height. Fertilization had no impact on vascular tissue terpenoid concentration. Previous studies have similarly demonstrated that nitrogen fertilization at a rate of 224 kg/ha had no impact on foliar terpenoids in grand fir while fertilization at 448 kg/ha reduced the foliar concentration of only a few individual monoterpenes. These results indicate that terpenoid production is not nutrient limited. In fact, nutrient-limiting

conditions have been shown to increase terpenoid production in conifers. Furthermore, increased cumulative growth due to fertilization did not negatively affect the concentration of constitutive terpenoid defenses in vascular tissue.

Overall, this research demonstrated no physiological tradeoff between growth and terpenoid defenses. Terpenoid content went up in proportion to increased tree growth resulting from improved light and enhanced nutrient resources. Terpenoid production is thought to be under strong genetic control. Thus, growth tradeoffs with defenses are probably expressed at the evolutionary level rather than the physiological level.

Title: Development and Evaluation of New Techniques for Resolving Predator Depredation Problems

Goal: Develop new or improved control technology systems for operational use in predator management.

Evaluating the Belisle Footsnare for Capturing Coyotes—Opposition to the use of foothold traps has led to accelerated research on alternative types of coyote restraining devices. One such device, the Belisle footsnare, was field-tested and evaluated by NWRC scientists in South Texas during February 1996. This device consists of a collapsible spring steel trap and a 3/32-inch cable snare with a sliding lock. Thirty coyotes were captured and held in this device during 900 trap nights of effort. An additional 17 coyotes were captured but escaped. Sixteen animals pulled out of the snare before it tightened on the leg, and one chewed through the cable. This resulted in a capture rate of 64 percent, which is much lower than that of most common coyote traps. Minor mechanical improvements and changes in the setting procedure would most likely improve capture success.

Trapped coyotes were collected and necropsied by a veterinary pathologist from the University of Wyoming. Individual injuries were assigned scores based on a trauma scale developed through the international standards process. Injuries such as edematous swelling and small cuts were similar to those observed for coyotes captured in padded traps. The mean injury score for coyotes caught in the Belisle footsnare was 19.7, which is similar to that for animals caught in the No. 3 Victor Soft Catch® trap.

Title: Development of Methods To Reduce Wildlife Damage to Agricultural and Forest Resources

Goal: Develop test, and implement methods to reduce wildlife damage to crops and property.

Radiotransmitters Tested for Extended Field Studies of the Pocket Gopher—Pocket gophers can cause substantial losses to reforestation and agricultural crops such as alfalfa. Efforts to evaluate existing populations and to develop new damage-control methods often rely on the use of radiotelemetry as a means of monitoring test animals in natural settings, but radiotransmitters can have adverse effects on the behavior of animals.

NWRC scientists at the Pullman, WA, field station evaluated four types of radiotransmitters for gophers on an Idaho field site over a 4-month period for the effects on the physical welfare and behavior of gophers as well as the signal detection and durability. Three of the transmitters were collar types: Model BR from AVM, Livermore, CA; an NWRC-manufactured collar; and PD–2C from Holohil, Ontario, Canada. The fourth transmitter was an implant type, model SOPI–1070–LD from Wildlife Materials, Carbondale, IL. Twenty-five of 46 gophers were radio-collared in the field with 1 of 3 collar models while 9 received surgical implant transmitters.

Twelve gophers served as nontransmitted controls. Gophers were monitored regularly, and those not recovered by the end of the study were captured and examined.

Recovery of marked animals and transmitters was quite high (85 and 82 percent, respectively), but transmitter shedding (35 percent) was common except for implants. Documented physical effects with the collar models were not common (9 percent), and no harmful effects of the implant surgery were evident. Radio-transmittered animals showed lower activity levels, but investigators detected no significant differences in weights of surviving control and transmittered animals. Of the four transmitter types, none emerged as a superior choice for extended field studies. The model that appeared the best had the longest lifespan, ranked well in size (small) and weight (low), was easy to attach, and had good signal strength.

Impacts of Grazing by Overabundant Ungulates on Biodiversity—Overabundant ungulates such as deer and elk cause damage to crops and other resources in many parts of the United States. Less well understood are potential impacts of grazing by wild ungulates on ecosystem structure and function. A graduate student at Washington State University, under guidance of the NWRC Pullman, WA, field-station biologist, studied the combined effects of wild and domestic ungulate grazing on plant and animal biodiversity in northeastern Oregon, using four large

enclosures paired with intensively grazed plots. Abundance and diversity of small mammals, shrub cover, and organic litter were substantially lower on overgrazed areas. No significant differences were detected in the abundance and diversity of birds and herbaceous vegetation. Birds are highly mobile and probably used areas inside and outside the enclosures. It appears that the effects of grazing on vegetation, birds, and small mammals may be a function of multiple factors such as habitat type, grazing history, and years of recovery. More substantial differences may be expected as the exclosure areas continue to adjust to cessation of grazing. Efforts to protect agricultural crops, timber, and forage from the effects of high- density ungulate populations are often conceived and examined as short-term problems. This work has demonstrated the utility of long-term research in understanding the recovery times associated with heavily grazed areas.

Product Development Research

Title: Development and Registration of New Rodent-Control Chemicals

Goal: Develop safe, effective chemical methods to reduce rodent damage to agricultural crops and rangeland, and to provide for public health and safety.

Evaluation of Hypochlorite Salt as a Fumigant for Controlling Northern Pocket Gophers—NWRC scientists evaluated hypochlorite salt as a fumigant for controlling northern pocket gophers. Hypochlorite salt has previously shown promise as a fumigant for controlling valley pocket gophers in limited field efficacy trials in California. To secure a Federal registration for this compound, EPA required additional field efficacy data gathered under Good Laboratory Practices. A private individual contracted with NWRC to collect these data.

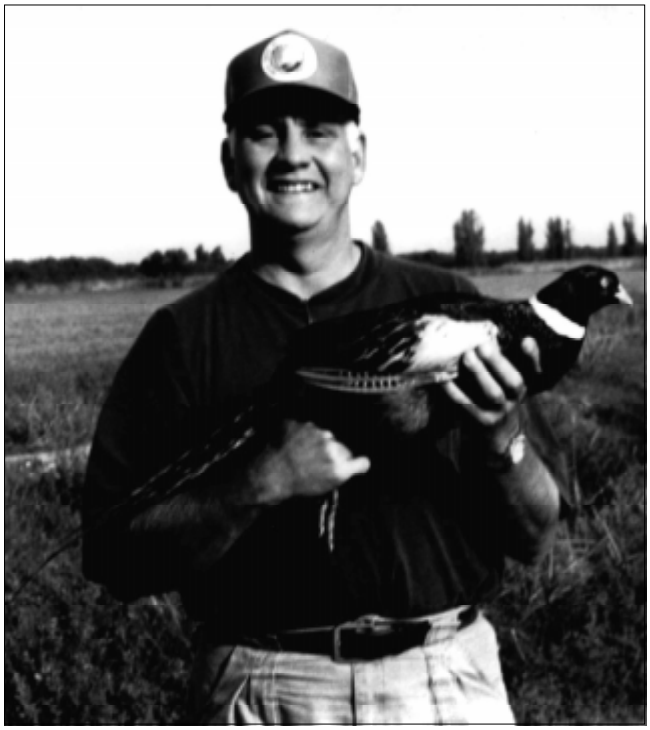
Four treatment areas were established in an irrigated grain–alfalfa hay field in Colorado. At active northern pocket gophers sites, 15 circular sample plots (1/50 acre) were established in each treatment area. Pocket gopher activity was measured before treatment by the open-hole index; pocket gophers were active on all 60 sample plots on the 4 treatment units. After fumigation with the hypochlorite salt, pocket gopher activity was remeasured. All sample plots on the three treatment units that were fumigated were active, whereas 93 percent of the sample plots on the single control unit were active. Under the conditions tested, hypochlorite salt was ineffective in controlling northern pocket gophers.

DuPont Oil Blue A: Biomarking Field Study With Northern Pocket Gophers—NWRC scientists continued to test the hypothesis that the availability of alternative food sources to northern pocket gophers during the alfalfa-growing season may be a major factor in reducing bait acceptance. Pocket gopher consumption of an oat groat bait was determined by preparing the bait with a biomarker. The bait was applied underground in an alfalfa field after the last alfalfa cutting. Five days after baiting, the bait sites were reopened and examined for the bait. Pocket gophers had consumed or transported all or most of the bait at 95 percent of 59 bait sites. Pocket gophers were then trapped and their fat examined for the presence of the biomarker dye. Of 24 pocket gophers trapped, 21 (87 percent) had ingested the bait causing their subcutaneous fat to be dyed blue. In males, the blue dye occurred in the fat surrounding the testes; in females, the blue dye occurred in abdominal fat and at the base of the tail. Three pocket gophers tested negative for the blue dye.

This high bait acceptance may have been due to a seasonal preference for the oat groat following the last cutting when the green alfalfa vegetation was absent. This result contrasts with results of a previous bait acceptance study conducted in growing alfalfa fields, where only 35 percent of trapped pocket gophers showed biomarker evidence of having ingested the treated bait.

Efficacy of Cholecalciferol for Control of Valley Pocket Gophers in California—The California Vertebrate Pest Control Research Advisory Committee funded a laboratory study at NWRC to determine the possibility that cholecalciferol could be registered with EPA to control Valley pocket gophers in California. Valley pocket gophers were captured in California and shipped to NWRC for a laboratory efficacy study of four concentrations of cholecalciferol-treated oat groats: 0.05 percent, 0.075 percent, 0.112 percent, and 0.169 percent. Groats used on control contained no cholecalciferol. A 1.5 geometric step increment among the treated baits was established around the 0.075 percent cholecalciferol bait currently registered in California for commensal rodent control. The study was a 3-day, no-choice feeding trial in which 100 animals were placed by weight into 20 weight classes and then randomly assigned to 5 treatment groups. Total mean bait consumption was 18.17 g for the control animals, 4.29 g for 0.05-percent, 4.08 g for 0.075-percent, 2.98 g for 0.112-percent, and 2.50 g for 0.169-percent-treated animals. The average weight of bait received by the animals in the treated groups was 13.53 mg per kg of body weight for the 0.05-percent bait, 19.55 mg/kg for the 0.075-percent, 21.39 mg/kg for 0.112-percent, and 27.95 mg/kg for the 0.169-percent bait. Mortality was 100 percent in the 0.05-percent bait class by day 8, 100 percent in the 0.075-percent by day 7, 100 percent in 0.112-percent class by day 10, and 95 percent in the 0.169-percent group by day 7. In conclusion, all cholecalciferol concentrations tested were highly successful in a laboratory situation, with an overall 95-percent mortality rate. However, the gophers were not given a choice of diets. Field testing of cholecalciferol is warranted as it has potential as a rodenticide for controlling Valley pocket gophers.

Risks to Pheasants From Zinc Phosphide Grain Baits To Control Voles in Alfalfa—Steamed rolled-oat bait (SRO) containing 2-percent zinc phosphide is used to control California voles in alfalfa fields. The risks of this bait to 39 wild-caught and 32 pen-reared pheasants were studied at two California sites in the Sacramento Valley near Meridian and Nicholas. Following the capture and radio-collaring of wild pheasants and acclimation of pen-reared birds to radio-collaring, birds were released into alfalfa fields. Several weeks after release of the pheasants, the alfalfa fields in two areas were cut, and the grain dried and baled. These fields were then broadcast-baited with either placebo baits or with zinc phosphide-treated baits. Field crews used radio telemetry to monitor habitat use and mortality of radio-collared birds daily before and after baiting and searched fields treated with zinc phosphide baits daily for animal carcasses after baiting.



In 815 checks of possible pheasant locations at the Meridian study site, radiotelemetry disclosed only 53 sightings (6 percent) in alfalfa fields, and 96 percent of those sightings took place before the grain was cut. These data indicate that pheasants rarely use alfalfa after cutting, either as foraging or resting habitat. Instead they used other crop and noncrop habitats as follows: rice (23 percent of locations), milo (45 percent), ditches (11 percent), corn (6 percent), orchards (5 percent), fallow fields (2 percent), melons (0.7 percent), and beans (0.4 percent).

The primary cause of death in 17 of the 20 pheasants (85 percent) found dead at the Meridian study site was avian and mammalian predation. One other bird was killed by hunters, one by harvesting machinery, and one died of unknown causes. Only 28 percent of the pen-reared pheasants at Meridian survived during the 4 weeks following release, while the survival rate among a comparable group of wild pheasants during 4 weeks after release and in the same area was 68 percent. Wild-caught male pheasants at Meridian moved daily an average of 290 m, and females moved 285 m; pen-reared pheasants moved greater distances daily, with males averaging 390 m and females, 327 m.

Of 927 pheasant locations determined using radiotelemetry at the Nicholas study site, pheasants were located in alfalfa fields 133 times (15 percent), and 96 percent of these occurred in alfalfa before harvest. Pheasant use of other crop and noncrop habitats was rice (30 percent), corn and ditches (each 15 percent), sugar beets (14 percent), fallow fields (7 percent), safflower (3 percent), sudangrass (2 percent), orchards (0.4 percent), and beans (0.1 percent). Avian and mammalian predation killed all 17 pheasants at the Nicholas study site. Only 29 percent of the pen-reared pheasants at Nicholas survived during the 4 weeks following release, while 74 percent of a comparable group of wild pheasants survived during the 4 weeks after release in the same area. Wild-caught male pheasants at Nicholas moved an average of 295 m daily and females moved 276 m; pen-reared pheasants moved greater distances, with males averaging 335 m and females 382 m.

These results indicate that SRO baits containing 2-percent zinc phosphide used to control voles shortly following the last harvest of alfalfa in northern California have little risk of causing nontarget poisoning of pheasants. Fresh-cut alfalfa fields were used by pheasants as resting or foraging habitat in only 4 percent of the radio locations. When bait was broadcast at 10 lb/acre, only 2.5 grains/ft^2 were present. No pheasants were found dead in alfalfa fields due to exposure to zinc phosphide-treated baits.

Title: Research and Development of New Repellent Technologies for Rodents

Goal: Develop new, effective, environmentally safe behavior/biological/chemical repellent methods for reducing rodent damage to agricultural crops/grasslands, above- and belowground cables, water impoundments, and farm buildings.

Pocket Gopher Barriers—NWRC scientists have begun evaluating novel gopher repellent products and technologies. One approach that offers potential for repelling gophers from designated areas is that of soil injection. The pest control industry developed this technology for treating soils adjacent to buildings with termiticides. In those situations, dilutions of registered termiticides are pumped between 1 and 2 ft below ground level adjacent to building foundations using a metal injector tube. The treated soils form a “repellent barrier” to movements of subterranean termites.

To test the feasibility of this approach on pocket gophers, NWRC researchers assessed soil-moisture preferences of gophers. Using a two-choice soil-test apparatus, gopher preferences for 5-, 10-, 15-, 20-, and 25-percent moist versus dry (0 percent control) soils were rated. The 15- and 20- percent moist soils were most preferred for digging and tunneling by gophers; the least preferred soil moisture was 25 percent. Based on this information, different repellent concentrations will be formulated and evaluated as underground barriers.

Title: New Solutions for Wildlife Problems Through Biotechnology: Immunocontraception of Wildlife Pest Species

Goal: Develop and field-test economical and effective immunocontraceptive vaccines to control populations of pest mammalian and avian species.

Avian Contraception—NWRC scientists, in cooperation with a CSU graduate student, are finding that the cholesterol inhibitor DiazaCon® holds promise as a potential avian oral contraceptive. Using the coturnix quail in laboratory experiments, DiazaCon was effective in inducing infertility in both sexes. In humans, DiazaCon is absorbed from the digestive tract into the bloodstream, where it mimics cholesterol and induces negative feedback (i.e., tricks the body into shutting down the synthesis of cholesterol). Orally ingested DiazaCon worked the same way in the coturnix quail studied. Cholesterol is needed for egg production and is the parent compound for sex hormone synthesis. Therefore, the drop in cholesterol induces infertility in both sexes in birds. DiazaCon would be effective only for species with seasonal breeding, however, because costs of continuous feeding would be prohibitive and it becomes toxic if fed for long periods of time. The single-period treatment effect appears to last several months.

Title: Development of Analytical Chemical Methodology for Wildlife Research

Goal: Develop and apply new analytical chemistry techniques and approaches to wildlife research problems.

Chemical Analysis of Rodenticide Residues— NWRC chemistry personnel developed and validated solid phase extraction-based methodology for the quantification of pesticide residues in a variety of biological matrices. These methods are being used to support a variety of NWRC studies including a Lipatech-sponsored laboratory secondary-hazard study for the rodenticide difethialone, a field efficacy study for the use of the rodenticide chlorophacinone to control ground squirrels, and a chlorophacinone residue study in range grasses following a broadcast baiting.

Sapwood Analysis—To support its research related to protecting forestry resources, the Center's analytical chemistry personnel used chiral gas chromatography and ion liquid chromatography-based methodology to analyze more than 300 sapwood samples from both bear-damaged and undamaged trees for terpene and carbohydrate content. These results are being used to correlate the chemical profile of sapwood with the likelihood of bear damage. The chemical composition of sapwood is also being correlated to silvicultural practices.

DRC–1339 Studies—Several studies were completed that increased the understanding of DRC–1339 chemistry in baits and the environment. In watermelon baits, nonenzymatic browning reactions between sugars and DRC–1339 were shown to be responsible for DRC–1339 degradation. A reaction product, –2 (4–Chloro–2–methylphenoxy)–propanoic acid (CMPP), was also identified. This product likely contributes to the aversion animals show to sunlight-exposed DRC–1339-treated baits. This reaction rate and the subsequent formation of reaction products were minimized by the addition of bisulfite to the baits, leading to increased stability of DRC–1339 in the baits. An evaluation of acceptance of the bisulfite-treated watermelon baits and aversion of CMPP will be undertaken in 1998. Also, a previously unreported soil metabolite of DRC–1339, azo–CPT, was identified in metabolism studies using soil from Louisiana rice fields.

Avian Repellants—Chemistry scientists are supporting field studies to evaluate avian repellants in rice-growing regions of Louisiana and Texas. Preliminary methodology based on patented Empore® extraction technology has been developed to quantify levels of candidate repellants in lakes and ponds near agricultural fields. Methods have also been developed to quantify levels of repellants on treated rice seed and in water during field evaluations. This work supports studies to test the efficacy of potential avian repellants for rice.

Rocky Mountain Arsenal Wildlife Refuge—Center scientists are assisting FWS and the U.S. Army with the conversion of the Rocky Mountain Arsenal Superfund site into a wildlife refuge. State-of-the-art methodology developed by NWRC chemists was used to analyze more than 500 wildlife urine and blood samples for organochlorine pesticide residues. Urine and blood residue levels are being correlated to whole-body residue levels and toxicological end-points. These methods will be used to determine the levels of pesticide residues in wildlife on the Rocky Mountain Arsenal Superfund site.

The project also has been requested to develop similar methodology to determine pesticide residues in wildlife brain, liver, and eggs. Correlation of residue results with ecological effects will be used to establish target cleanup levels for the Arsenal. Funding for this work is being provided by the Department of Defense (DoD). The methods being developed have direct application to pesticide use by Wildlife Services.

Title: Development and Registration of an Oral Tranquilizer Trap Device

Goal: Develop and receive FDA authorization for use of an oral tranquilizer trap device (TTD) for capturing coyotes, wolves, foxes, and other predators.

Tranquilizer Trap Device for Capturing Wolves— Leghold traps are sometimes required to capture gray wolves for reintroduction to new areas, to relocate animals to curtail agricultural depredation, or to form part of scientific investigations. Recent studies evaluating the use of TTD's attached to traps used to capture wolves indicate that the TTD can lessen foot and leg injuries by more than 75 percent.

A TTD is a small, tubular device filled with an oral tranquilizer, propiopromazine, that is attached to one of the jaws of a trap attached to a drag. Trapped animals typically bite and chew on the device and ingest the tranquilizer. Average injury scores, based on necropsy data, decreased from over 85 in traps without tranquilizers to less than 25 when TTD's were used. Similar reductions in injury were noted among other species incidentally captured in traps set for wolves; no animals succumbed to an overdose of tranquilizer.

Added benefits of using TTD's are easier recovery of animals from unstaked traps because they do not travel as far and reduced escape rates because struggles are less intense. TTD's appear to increase both the efficacy and humaneness associated with use of leghold traps.

Registration and Reregistration Status

Pesticides, Drugs, and Vaccines for WS—The WS program manages wildlife–human conflicts by using an integrated approach employing a small number of vertebrate pesticides. These are used in such small quantities that private industry cannot afford to register and produce them profitably. APHIS, therefore, maintains registrations for seven active ingredients with EPA: Compound 1080 (Livestock Protection Collar), DRC–1339 concentrates (Starlicide), gas cartridges (carbon and sodium nitrate), sodium cyanide (M–44), and strychnine alkaloid and zinc phosphide baits and concentrates. APHIS also maintains registrations for about 25 to 30 individual end-use products, 1 Experimental Use Permit, and 2 vertebrate drug active ingredients. NWRC maintains a registration unit in the Product Development Research program that is responsible for meeting the data requirements imposed by EPA for maintaining these products.

During 1997, product development personnel coordinated 3 consortia that have a combined responsibility for more than 90 vertebrate pesticide registrations and are investigating APHIS participation in a new consortium for Mesurol. Product development personnel regularly meet with EPA and FDA personnel to address registration issues for WS pesticides, drugs and vaccines. The registration unit was also responsible for applying for a new registration for an end-use product with a new active ingredient (Mesurol), and applying for two Investigative New Animal Drug (INAD) authorizations for vaccines used as immunocontraceptives.

Reregistration Status and Activities—In 1988, Congress amended the Federal Insecticide, Fungicide and Rodenticide Act, requiring reregistration of all older pesticides. Reregistration has had an extensive impact on the WS program. Nearly 433 studies, costing over $13.6 million, were requested by EPA for APHIS products. Through negotiations with EPA, repackaging of old data, and requesting data waivers for inappropriate studies, NWRC personnel reduced the data requirements to 258 studies costing $3 million. In addition, NWRC developed consortia to generate funds to maintain strychnine and zinc phosphide products held by private industry and State agencies. APHIS is entering the final stages of the EPA reregistration process for WS vertebrate pesticides. Due to NWRC efforts, five active ingredients (carbon, sodium nitrate, sodium cyanide, Compound 1080, and DRC–1339) have been reregistered and all data requirements (except for data required for the end-use products) have been met. In addition, data submissions required by the Data Call-In for strychnine have been completed, and EPA issued the Reregistration Eligibility Decision (RED) for strychnine in March 1997. Subsequent negotiations with EPA resulted in a significant reduction in the amount of remaining data requested—a reduction that should allow APHIS and the Strychnine Consortium to achieve reregistration for technical strychnine and strychnine end-use products in fiscal year (FY) 1998. A RED is expected to be made within the next year on zinc phosphide, the only remaining APHIS vertebrate pesticide awaiting reregistration.

Data Submissions and Reports—NWRC is responsible for developing or obtaining all the data needed to meet APHIS and consortia commitments to EPA and FDA on behalf of the WS program. The NWRC registration unit manages all data-gathering activities and coordinates these activities with the data support team in APHIS' Policy and Program Development unit. During FY 1997, NWRC conducted, contracted, and/or prepared 23 data submissions for 5 vertebrate pesticides and 1 drug. These submissions represented contracts or studies that have been underway for up to 2 years and represented a combined direct APHIS–consortia investment of more than $350,000. In addition to the data submissions, NWRC also prepared 17 annual, semiannual, or quarterly reports for EPA or FDA on behalf of APHIS or the consortia. These reports are required by the regulatory actions of EPA and FDA.

Significant Registration Activities—Registration unit personnel have been active in providing required data and technical support to allow APHIS to make label changes to existing vertebrate pesticides. Of particular interest to the WS program is reducing the length of the fallow period required following the use of DRC–1339 in rice. NWRC has been negotiating with EPA to allow a reduction in the fallow period without classifying this use as a food use, a condition that would require more than a million dollars worth of additional studies. NWRC personnel are working with stakeholders to obtain funding for a crop rotation study using radiolabeled DRC–1339 to quantify its uptake into plants. APHIS also requested changes in the DRC–1339 gull label to expand its use throughout the continental United States; EPA is expected to approve the new label in the near future. The gas cartridge was converted from four active ingredients to two this year. Finally, NWRC personnel assisted the Pocatello Supply Depot with implementation of formulation changes for a number of their rodenticide products because of the installation of new and improved formulation equipment.

New Pesticides and Uses—During FY 1997, NWRC personnel have worked with personnel from the Gowan Company, a small specialty pesticide producer, to begin the process of obtaining EPA approval for registration of Mesurol as an aversive conditioning agent and bird repellant. An application for Mesurol 75 percent Wettable Powder Aversive was made by APHIS in May 1997. This label would allow use of Mesurol in decoy eggs to deter ravens and crows from feeding on eggs of endangered and threatened species. In early 1997, Gowan requested that a Mesurol 50 percent Hopper Box formulation be registered for reducing bird damage to sprouting corn. Gowan and APHIS also are interested in bringing back the registrations for Mesurol application to control bird damage on soft fruits. NWRC is actively soliciting uses for low-risk chemicals that have been exempted from regulation by EPA, particularly for use as repellants.

Significant Drug or Vaccine Activities—In addition to continuing to coordinate NWRC use of alpha-chloralose, registration unit personnel have begun to develop semiannual reports on use of the TTD and have assisted in developing a TTD Training and Use Guide for WS operational personnel. The guide should be distributed to WS State Directors in 1998. Based on results of research, NWRC has received two INAD authorizations for APHIS immunocontraceptive vaccines. The first INAD was developed for controlling deer and coyote populations with a porcine zona pellucida vaccine, and the second was developed for a gonadotropin-releasing hormone vaccine for use in deer, coyotes, and rodents.

Pesticide and Drug Registration Files—Registration unit personnel have completed a data base which will allow APHIS and NWRC personnel to access the status of individual data requirements for all APHIS or Consortia vertebrate pesticides. This cross-referenced data base will be made accessible online in late FY 1998 through the NWRC Library's local area network. Similar efforts have been expanded to obtain, input, and complete a series of data bases that contain information on 22 pesticides and drugs of interest to the WS program. Individual citations, along with descriptor terms, have been entered for all 22 pesticides. These data will also be accessible online through the NWRC Library's ProCite™ data base. Finally, NWRC personnel completed a 2-year project in FY 1997 to place all 6,800 chemicals and other materials that were screened between 1960 and 1987 by NWRC for pesticidal and repellent properties into a searchable data base. The data base contains DRC numbers, chemical names, and Chemical Abstracts Service registry numbers for all identified compounds. In addition, the data base indicates the type, quantity, and location of data developed by NWRC and provides access to summary or raw data for research purposes. The data base will be accessible online through the NWRC Library's local area network and referenced data will reside in the NWRC archives.

Data Provided to State Regulatory Agencies and Cooperators—Center personnel continue to routinely interact with the California Department of Pesticide Regulation (CAL–EPA) to allow the use of APHIS pesticides to continue in that State. Other States are also following in CAL–EPA's footsteps by requiring extensive data, which NWRC is providing on an as-requested basis. In addition, WS program personnel or cooperators often need access to, or summaries of, data produced by NWRC or others to include in Environmental Assessments, Environmental Impact Statements, and in Section 7 consultations with FWS. NWRC is the prime supplier of these data to the WS program and its cooperators, often including summaries and necessary interpretations. More than 150 significant requests were handled in FY 1997; most were partially or completely customized for the requester.

Title: Development of Chemical Control Methods for Brown Tree Snake Management

Goal: Develop techniques to help control brown tree snakes on Guam and prevent their dispersal from that island.

NWRC has been conducting research since 1995 with funds provided by the DoD Legacy Program to develop chemical methods to control brown tree snakes (BTS) on Guam. To date, several cargo fumigants and commercially available toxicants for use by the homeowner have been identified. Research continues on field toxicants and delivery systems, attractants and repellants. These research areas were stressed in 1997.

Evaluation of Toxicant Delivery Devices—Previous studies identified three pesticides as having potential as dermal toxicants for BTS. However, no practical, environmentally acceptable devices for delivering the toxicants to snakes are available. During FY 1997, several cardboard devices and live traps were evaluated as toxicant delivery devices. Each cardboard device and trap had a crawl-through opening and an aluminum foil "crush tube" for indicating visits by snakes. Transect lines were established that consisted of random placement of these devices with and without lures (dead or live mice) in several types of habitats. The mean overall visitation rate was 0.5 percent and 4 percent for devices without and with a lure, respectively. The mean visitation rate for the live trap with a dead mouse lure or a live mouse lure was 14 percent and 20 percent, respectively. These results indicated that snakes prefer live traps to the cardboard devices and that snake visitations for this test increase in the presence of a lure.

Development of an Inanimate Lure and Attractants—The goal of this research is to identify the important components of an inanimate lure. To date, it appears that a chemical lure based on live prey odors requires the presence of a visual cue to be effective. In the presence of a visual cue, carrion odor was always an effective lure. However, there were seasonal differences in the efficacy of carrion odor lures and size differences in the snakes attracted to these lures; smaller snakes appear more likely to be attracted. Although carrion is an effective lure, using carrion operationally is not feasible given its rapid rate of decomposition on Guam. No common chemical agents associated with carrion odor, tested individually or in simple combinations, proved effective. Future research focuses on identifying the chemical components of carrion, testing the attractiveness (trapping success) of carrion fractions, and blending and reconstructing combinations of synthetic compounds to simulate active fractions and test their efficacy as lures.

Identification of Snake Repellants—The goal of these efforts is to identify compounds that can be used to drive snakes out of enclosed spaces. Frequently, teams of snake-detecting dogs identify cargo as containing snakes. As a first effort to extract the snake, a fumigant would be used to promote escape behavior. This method would promote efficient snake control because it would not require dismantling cargo identified as possibly containing snakes. NWRC scientists evaluated several compounds derived from Food and Flavor Codexes to determine if the compounds promote escape behaviors in snakes. Of the 30 natural products or compounds screened for activity, 8 compounds showed potential as repellants. For these compounds, snakes responded within 0 to 5 minutes after initial exposure by demonstrating vigorous escape behavior. These compounds will be evaluated as aerosols for driving snakes in simulated cargo situations.

Analytical Chemistry Methodology and Validation—During FY 1997, NWRC completed and validated analytical chemistry methods to quantify pyrethrins in BTS. Limits of detections for six naturally occurring pyrethrins were less than 10 parts per billion. This method was then used to determine pyrethrin residues in snakes which were both orally and dermally dosed with pyrethrins on Guam. For snakes orally dosed at 20 mg/snake, whole-body residues averaged 68 μg/g (range 14–123 μg/g). For snakes that received an oral dose at 40 mg/snake, pyrethrin residues averaged 162 μg/g (range 4–501 μg/g). The mean residue in fatally dosed snakes was 188 μg/g. The mean residue in surviving snakes was 100 μg/g. For dermally dosed snakes, pyrethrin residues were significantly lower, averaging only 15.7 μg/g.

NWRC personnel also configured analytical chemistry equipment to link purge and trap technology with a mass spectrometer to permit the identification of potentially volatile snake attractants. This system was used to identify and quantify potential volatile snake attractants or lures in decaying mice, which were and will continue to be the basis for some of the attractant research on Guam. During FY 1998, NWRC chemists will complete residue analysis of rotenone in snake tissue, investigate microencapsulation of toxicants to increase the stability in the stomach of the snake, and possibly also investigate potential carriers to increase the transport of toxicants across snake skin.

Improving Effectiveness of Dog Team Searches and Operational Trapping—NWRC dog team and trap research is conducted with funds provided to WS Operation's Washington State office and is obtained from the DoD under DoD MIPR–064–95, "Operational Control of Brown Tree Snakes in Guam." The goal of dog team evaluations was to determine the efficacy of the dog teams for locating snakes in cargo and better understand why snakes may be missed during inspections. With an observer present, the dog teams were effective at locating the great bulk (80 percent) of planted snakes. Without an observer present, the efficacy during inspections in the transition period was 38 percent. However, after snakes had been routinely planted prior to inspections without the handlers' knowledge, the efficacy nearly doubled to the current level of 70 percent in the posttransition period. Based on the data from inspections with an attending or concealed observer, researchers concluded that the snakes not located during inspections were missed because of nonresponses by the dogs or an insufficient search pattern by the handlers.

The goal of trap evaluations has been to help increase the effective operational use of traps. Past research has stressed evaluating the efficacy of different trapping locations (perimeter and interior) and increased trap spacings. The current operational approach of perimeter trapping on plots of forested land is highly effective for removing the trappable-sized BTS. It can virtually remove snakes from plots up to 8 ha in size and, with maintenance trapping, keep these plots nearly snake free. The efficacy of perimeter trapping in a 17-ha plot is currently being tested. Reinvasion in the absence of trapping has been relatively slow.

International Cooperation

Meeting on Rodent Integrated Pest Management (IPM) in Tanzania—An NWRC scientist participated in the International Workshop on Rodent Biology and Integrated Pest Management in Africa in Morogoro, Tanzania, October 21–25, 1996. This rodent conference, hosted locally by the Sokoine University of Agriculture, was attended by 60 participants from 25 countries on 5 continents. The keynote address was presented by Dr. Norman Gratz, retired World Health Organization rodent zoonoses expert, who provided an excellent historical perspective on African rodent problems and the efforts made to find solutions. Papers included research on rodent taxonomy, behavior, population dynamics, reproduction, zoonoses, and on IPM techniques and implementation. This workshop provided evidence that the amount and variety of research, extension, publication, and management programs occurring in Africa has increased manyfold over the last decade.

Presentations focused on the two most important rodent pests in Africa, *Mastomys* and *Arvicanthis* spp., but research papers on *Taterillus*, *Lophuromys*, *Aethomys*, *Rabdomys*, and *Rattus* spp. were also delivered. Other papers highlighted new developments in nonlethal control techniques such as immunocontraception, barrier trapping, and habitat management. Public health concerns about several zoonoses involving rodents were raised, and related papers covered plague, leishmaniasis, leptospirosis, schistosomiasis, bacterial antigens, and Lassa fever. Also, communication among farmers, extension workers, and decisionmakers in national rodent-management programs for sustaining agriculture was stressed.

Hungary—Scientists from Pannon University of Agriculture Sciences, Keszthely, Hungary, and USDA Agricultural Research Service (ARS) visited NWRC's Sandusky, OH, field station in November 1996. The Hungarian scientists presented a seminar on deer repellents and exclusion devices currently being developed in Hungary and Austria. As an outgrowth of this meeting, NWRC scientists are developing a research plan that will evaluate and integrate techniques developed in each country for reducing deer use of airports and deer damage to agricultural crops.

Mexico—NWRC has continued collaborative consultation and research with investigators at the National University of Mexico (UNAM) in Mexico City on studies of pocket gophers, which cause extensive agricultural losses in a wide variety of crops in Mexico. Several manuscripts have been produced, and studies are continuing on a variety of topics concerning pocket gopher damage problems in Mexico, particularly to sugarcane.

Australia—NWRC has continued working with zoologists from the Department of Natural Resources in the Queensland, Australia, State Government, focusing on dingo predation of livestock with an initial emphasis on evaluating methods for indexing wild canid populations. A passive tracking station was developed and found to be the most sensitive to the presence of wild canids. It also is sensitive for indexing other species present in the area that may have population responses to changes in dingo populations. This activity index is unusual in that the method defines a data structure for which a specific variance formula could be derived, rather than depending only on ad hoc procedures applied to a sampling plan.

Sweden—NWRC is collaborating with a biologist at the Swedish University of Agricultural Sciences on a study using fully enumerated field populations to evaluate plotless density estimation methods, which have particular applicability to assessing animal damage. These results support the conclusions from a previous simulation study directed by an NWRC investigator that used theoretical population patterns.

Valuing and Investing in People

Public Health Awards

Robert McLean, NWRC bird research program manager, was a member of the Ebola Hemorrhagic Fever Epidemic Response Team while employed by the Centers for Disease Control and Prevention (CDC). The team mounted a multifaceted response to the ebola hemorrhagic fever epidemic in Kikwit, Zaire, in 1995. Dr. McLean was responsible for the sampling of birds and bats as possible natural hosts of the virus in the epidemic area. This Ebola Response Team received the 1996 Outstanding Unit Award and the Department of Health and Human Services Secretary's Award for Distinguished Service for its efforts.

Wildlife Society Award

On October 6, 1996, the southeastern section of The Wildlife Society presented a special recognition award to Edward P. Hill for his "outstanding research service and leadership in the conservation of furbearer resources." During his 35-year career, Dr. Hill's work covered such subjects as beaver, river otter, red and gray foxes, cottontail rabbits, raccoons, coyotes, wood ducks, double-crested cormorants, and blackbirds. Hill served as chief of bird research at the DWRC between January 1992 and August 1995.

Outstanding Wildlife Professional Award

Richard Dolbeer, project leader of the NWRC Ohio field station, received the Berryman Institute's 1996 Outstanding Wildlife Professional Award at the third annual Wildlife Society Conference in Cincinnati, OH, in October 1996.

USDA Award for Superior Service

Dolbeer also received the USDA Award for Superior Service in June 1997 for "outstanding contributions and leadership in enhancing aviation industry safety by developing effective methods of reducing wildlife collisions with aircraft."

Information and Communication

Information Services

Information and Technology Transfer—NWRC produced a new exhibit that illustrated the Center's research mission and research projects. The exhibit was displayed at the 1997 Wildlife Society Meeting in Snowmass, CO. NWRC's FY 1997 publications included the FY 1996 highlights report, the summer 1997 "NWRC Research Update," "Contraception in Wildlife Management" (USDA Technical Bulletin 1853), and the "Repellents in Wildlife Management Symposium Proceedings." Copies of these publications are available from the NWRC library. NWRC also provided several hundred information packages on a variety of wildlife damage topics and information about the Center's research projects.

NWRC Library—Center personnel continued their important role of disseminating information to a large number of individuals within the WS program, as well as to other clients, customers, and the general public. The NWRC library conducted more than 300 literature searches and provided information on such diverse subjects as pigeon control, feral cat repellants, white-tailed deer damage to crops, auditory and sensory repellants to birds, chemical structures of pesticides, gopher food habitats, and more. The library mailed more than 7,000 NWRC author reprints to requesters. The 1996 Annual Publication List containing 87 citations was compiled and distributed. The library requested more than 1,300 books and photocopies from other institutions and, in return, sent more than 600 items to outside requesters. In addition, more than 1,200 photocopies from NWRC library holdings were sent to individual requests. The library continues to make increased use of electronic document delivery and a listserver that sends journal tables of contents to biologists automatically.

A major accomplishment this year is the completion of NWRC's Internet home page which can be found at http://www.aphis.usda.gov/ws/nwrc. Information on the NWRC Web page includes a description of the Center and its research activities, a forum for updating current activities, a guide to all of the NWRC field stations, and a description of the library and archives services available. The serial holdings, various publications (including the 1995 and 1996 versions of this highlights report and the 1996 Annual Publication List), downloadable images of wildlife damage, a staff directory, and a listing of current research priorities and projects can also be found on the homepage.

NWRC Archives—Despite relocation from Denver to Fort Collins, all Good Laboratory Practice and research material continued to be archived. The archives unit also received large quantities of materials from retiring employees. This material, representing over 30 years of research in many cases, has been organized and added to the archives collection. Archives staff collaborated with the quality assurance staff to complete a new quality-assurance data base that tracks the status of Good Laboratory Practice studies and provides statistical information in a report format. Thirty-eight studies, six chemical methods, and three chemistry notebooks were accessioned into the archives.

Seminars

NWRC continued to be a focal point for interesting seminars by its own and visiting scientists. A total of 19 seminars were presented on such diverse topics as damage by birds and predators to aquaculture and livestock industry, product formulation, brucellosis in bison in Yellowstone National Park, rodenticide use in New Zealand, and brown tree snake control on Guam.

NWRC Seminars

Speaker	Affiliation	Title
Tommy King	NWRC—Starkville, MS	Aquaculture Research at NWRC's Mississippi Field Station
Jack Rhyan	APHIS, Veterinary Services	Epidemiology and Pathogenesis of Brucellosis in Bison in Yellowstone National Park
Lowell Miller	NWRC—Ft. Collins	New Solutions for Wildlife Problems Through Biotechnology
Bruce Warburton	Manaaki Whenua Landcare Research, NZ	Physiological Response of Brushtail Possums to Capture in Leghold and Cage Traps
Peter Savarie	NWRC—Fort Collins	Tranquilizer Trap Devices
Jean Bourassa	NWRC—Fort Collins	Geographic Information Systems: A Technical Overview
John Johnston	NWRC—Fort Collins	Analytical Chemistry Method Development for Wildlife Research
Mike Jaeger	NWRC—Berkeley, CA	Sheep Predation in North-Coastal California: Selective *v.* Nonselective Control
Gary Witmer	NWRC—Pullman, WA	A Research Overview of NWRC Pullman Field Station
Jerome Hurley	Ecogen, Inc.	Formulation of Phermones
Kim S. Larson	Danish Pest Infestation Lab—Lyngby, Denmark	An Evaluation of Plague Situation in Lushoto, Tanzania
Peter Samuel	Abbott Labs, Inc.	Formulation of Pharmaceuticals
David Skogberg	Staley Starch, Inc.	Formulation of Flavor Ingredients
Kenneth Cole	National Institute of Standards and Technology	Formulation With Starches
Todd Felix	NWRC—Fort Collins, CO	Recombinant Salmonella as a Vector for Oral Immunocontraceptive Vaccines
Earl Campbell	NWRC—Hilo, HI	Predatory Impact of Brown Tree Snakes on Guam

Meetings, Workshops, and Conference Presentations

Summaries of some selected presentations show both the diverse nature of NWRC's research and its varied stakeholder and interest groups. NWRC scientists make significant efforts to get research information out to the scientific community, customers, clients, and the public in general.

Wildlife Society Mississippi Chapter Annual Meeting—Mark Tobin gave a presentation in October 1996 to the Mississippi chapter of the Wildlife Society in Roosevelt State Park, MS, on research being conducted by NWRC to reduce bird depredations at aquaculture farms.

Management of Problem Wildlife, University of British Columbia, Vancouver, BC, Canada—Dale Nolte presented a talk in October 1996 on approaches to reduce negative impacts of wildlife to forest resources.

Monell Chemical Senses Center, Annual Sponsors' Meeting—In October 1996 in Philadelphia, NWRC biologists presented research displays on coyote lures and mammal and bird repellants, and Larry Clark gave a talk on chemosensory methods for avian and snake repellancy.

Stand Management Cooperative (SMC) Annual Policy Meeting—Chemist Bruce Kimball presented a paper entitled "DWRC Research on SMC Installations" Olympia, WA, in November 1996. The presentation described research regarding the impacts of silvicultural practices on the chemical constituents of Douglas-fir vascular tissue. Common thinning and fertilizing treatments greatly affect the quantities of chemical constituents in vascular tissue, and these chemical profiles are, in turn, related to bear foraging preferences.

Bird Strike Committee Canada—Richard Dolbeer and Sandy Wright of the Ohio field station staff attended the annual meeting of Bird Strike Committee Canada in November 1996 in Ottawa, ON, Canada. The biologists met with a representative from the International Civil Aviation Organization (ICAO) to discuss standardized coding used in the U.S. National Birdstrike Database. This data base, which the Ohio field station manages for the FAA, contains records of more than 15,000 bird strikes to civilian aircraft in the United States from 1990 through 1996. ICAO is incorporating these records into their worldwide data base. Information contained in these data bases is crucial for defining the extent and nature of bird strike problems for airports throughout the world so that corrective actions can be justified and taken.

Ohio Coordinating Committee for the Control of Depredating Birds—NWRC scientists of the Ohio field station presented research findings at the annual meeting of the Ohio Coordinating Committee for the Control of Depredating Birds in December 1996 in Columbus, OH. The committee, comprised of representatives from agriculture, the pest control industry, State and Federal agencies, and universities, has met annually since 1965 to discuss vertebrate pest problems in Ohio and to provide direction for research and management efforts. Two major areas of discussion at the 1996 meeting regarded continuing problems with the timely issuance of permits for various bird-damage situations and the desire of some private pest control firms to use alpha-chloralose for capturing pest birds under the supervision of the WS program. In addition, concerns were expressed regarding increased blackbird damage to sweet corn, increasing coyote populations, the spread of rabies by feral cats, and damage to rubber roofing and window caulking by turkey vultures.

Oregon Forest Industry Council Annual Meeting—NWRC scientists presented a paper on the relationship of chemical constitutents and bear foraging in Douglas-fir vascular tissue to the Oregon Forest Industry Council in January 1997 in Philomath, OR.

Sunflower Research Forum—Scientists from the NWRC North Dakota field station presented papers at the Sunflower Research Forum in January 1997 in Fargo, ND. Papers included information on reducing

blackbird damage to sunflower, the status of avicide research, and what progress has been made on identifying the nontarget hazards associated with the use of DRC–1339 avicide in South Dakota.

Armed Forces Pest Management Board Meeting— NWRC again participated in the annual meeting of the Armed Forces Pest Management Board in January 1997 at the USDA ARS conference center in Gainesville, FL. This annual meeting details USDA research of interest to the DoD and provides the basis for DoD recommendations to USDA for future research activities. USDA representatives from ARS and the Forest Service also were present. NWRC presentations covered the overall research activities at the Center, an update on the status of the Center's move from Denver to Fort Collins, an update on brown tree snake research, and Center research accomplishments and plans related to wildlife hazards to aircraft. NWRC presently receives funding from DoD and FAA for research in these areas.

The 113th Annual Convention of the Ohio Veterinary Medical Association—Richard Dolbeer made a presentation entitled "Impact and Management of Birds in the Feedlot Environment" in February 1997 in Columbus, OH. The talk reviewed the role of wild birds in the spread of livestock diseases, the various management tools available to reduce livestock food consumption by birds, and bird–livestock contact. Dolbeer emphasized the importance of prebaiting, careful monitoring, bait-site selection, and bait containment as essential to minimize nontarget exposure.

Wildlife Society, Western Section Annual Conference—NWRC biologists and their graduate students presented papers in February 1997 in San Diego, CA. The papers reported results from three studies being conducted at the Berkeley, CA, field station: monitoring coyote, jackrabbit, and rodent abundances at two sites in the intermountain region over a 30-year period; a 7-year study in eastern Colorado in which 50–70 percent of the coyotes were removed from an unexploited population; and ongoing sheep predation research at the Hopland Research and Extension Center in California.

Mississippi State University Seminars—In February 1997, Dale Nolte gave two seminars on wildlife damage management. "Mammal Conflicts: Identifying Wildlife Damage to Forest Resources and Means to Alleviate Negative Impacts" was given as part of the Principles of Wildlife Damage Management course at the University in Starkville. Nolte also gave a talk entitled "Tree Selection by Foraging Black Bears: Management Implications" in a Fish and Wildlife Department seminar.

Pittsburgh Conference on Spectroscopy—Chemist Tom Primas presented a paper entitled "Analysis of Difethialone Residues in Whole Body Rodents" in March 1997.

Wildlife Society, Washington Chapter Annual Meeting—Biologist Gary Witmer presented a poster entitled "Ungulate Effects on Biodiversity and Carnivore Conservation and Management" in March 1997 in Yakima WA.

University of Pennsylvania, Department of Biological Chemistry Seminar—Russ Mason gave a seminar in Philadelphia in April 1997 on the subject of chemical ecology and wildlife management.

University of Tennessee at Martin Seminar—Mark Tobin gave an overview of NWRC research to reduce bird depredations at aquaculture farms to a class in April 1997.

Rocky Mountain Wolf Conference—NWRC scientists presented two papers on the merits of using TTD's on leghold traps used to capture gray wolves and evaluating trap-related injuries using injury scales at the Wolf Field Techniques Workshop in Emigrant, MT, in April 1997.

The 13th Great Plains Wildlife Damage Control Workshop—Several NWRC scientists presented research papers or chaired technical sessions in April 1997 in Nebraska City, NE. Many WS Western Region employees also attended. Highlights of the 3-day workshop included sessions on media and public communication and WS research; use of field

techniques, such as leghold trapping, bird-scare protechnics, etc.; dual platform sessions; and a field trip to illustrate wildlife damage management issues related to birds, urban deer, and prairie dogs.

The 9th Northern Furbearer Conference—Bob Phillips presented a poster session describing NWRC's contributions to advances in trap and snare technology in Yellowknife, NT, Canada in May 1997. The meeting was attended by 60 fur managers and researchers from Canada, the United States, and Sweden. He also participated in a panel discussion with representatives from Canada and Sweden on the status of the European Union fur ban. Canadian officials recently negotiated an agreement with the Union which calls for phasing out the use of legholds in Canada by 1999.

The 6th Western States Black Bear Workshop—Dale Nolte presented several posters and a paper at Ocean Shores, WA, in May 1997. The posters illustrated black bear use of roads and black bear conservation and management in the interior Pacific Northwest. The paper reviewed the collaborative effort between NWRC and the Washington State Animal Damage Control Program to address constraints to reduce black bear and other animal damage.

Controlling Coyote Predation on Sheep in California: A Model Strategy—Karen Blejwas, an NWRC–University of California graduate student, gave a presentation to the California Department of Pesticide Regulation Research Advisory Group's semiannual meeting in May 1997. The presentation was an update of recent coyote research on the UC–HREC with emphasis on efficacy of selective targeting of sheep-killing coyotes.

Pennsylvania Fish Depredation Workshop—In July 1997, Tommy King gave an overview of research conducted at the NWRC Mississippi field station to workshop attendees at the Middle Creek Wildlife Management Area.

The 7th Annual Meeting of Bird Strike Committee–USA—About 300 people attended this meeting at Logan International Airport, Boston, MA, in August 1997. The meeting, which received local and national newspaper and TV coverage, was organized by WS and NWRC biologists from Massachusetts and Ohio in cooperation with airport personnel. In all, 42 technical papers and posters were presented on topics related to reducing wildlife collisions with aircraft. John Goglia, a member of the National Transportation Safety Board, and Mike Dunn, Assistant Secretary of Agriculture for Marketing and Regulatory Programs, gave keynote addresses. Special sessions were held on new technologies for aircraft avoidance of birds and airport falconry. Twelve companies exhibited their wildlife management products. The goal of the Committee is to increase communication and professionalism among the diverse groups dealing with wildlife issues at airports.

The First European Vertebrate Pest Conference—Two NWRC scientists presented papers in September 1997 at this inaguaral meeting, hosted by Britain's Central Science Laboratory in York, England. Scientists and industry representatives from 41 countries attended. NWRC scientists presented papers on methods for the systematic identification of repellants and methods of deer control. Several potential collaborative projects with the Laboratory and other NWRC counterparts in several nations were discussed. Due to the success of the first European Pest Conference, it was decided to hold future conferences on alternate years, opposite to those of the American Vertebrate Pest Conference.

Mammal Trapping Symposium—Two NWRC biologists participated in this symposium held in Edmonton, AB, Canada. The NWRC scientists presented papers on trapping pocket gophers and bobcats. About 60 people from 7 countries discussed issues, methods, and types of traps. The continuing efforts to achieve international trap standards were the impetus for the symposium. A wide array of perspectives were represented at the meeting with presentations on all aspects of trapping. Several

Canadian researchers presented results on the effectiveness and humaneness of new trap types. A working group was formed to foster future interaction and information dissemination.

The Fourth Annual Wildlife Society Conference— NWRC biologists attended this meeting held in Snowmass, CO, in September 1997. They presented papers and posters on blackbird damage to rice; the effectiveness and hazards of various chemicals, repellants, and rodenticides; managing predation on avian species; flavor avoidance learning; reducing coyote predation on livestock through selective control and immunocontraception; silvicultural management practices and black bear foraging; and studies on pocket gophers, mountain beavers, and the foraging ecology of adult female mountain lions.

NWRC Scientist Helps Assess Hantavirus Hazard to Wildlife Researchers—Gary Witmer, project leader at the NWRC Pullman, WA, field station, was invited to assist a subcommittee of the Institutional Animal Use and Care Committee of Washington State University in developing guidelines to reduce the risk of hantavirus exposure for research biologists working with rodents. Hantavirus was identified as a cause of serious zoonotic disease after the 1993 outbreak in the Southwestern United States. More than 165 cases have occurred, mostly in the Western States and across a wide array of age, gender, and race. Wildlife biologists are considered to be a high-risk group, but less than 1 percent of over 900 biologists tested by CDC personnel were seropositive (indicating past exposure to the virus). Pullman field station personnel assisted in the testing of about 70 biologists in Washington, all of whom proved negative for hantavirus exposure. Basic precautions include the disinfection of potentially contaminated surfaces, equipment, and traps, and the use of personal protective equipment (gloves, gowns, and respirators).

NWRC Tours

Center employees conducted more than 50 tours of the NWRC's Animal Research Building and other offices for a diverse group of visitors in 1997. Groups included the Jefferson County Master Gardeners, EPA, DoD, CSU Wildlife Department, the GoreTex Corp., Sunlight Tool Company, APHIS–Veterinary Services, and individual scientists.

Publications

Listed below are FY 1997 publications by NWRC authors that were in print at the time this report was prepared. NWRC staff members are highlighted.

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