2nd National Invasive Rodent Summit

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October 19-21, 2004

Hosted by:
USDA/APHIS/Wildlife Services
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Sponsored by:
USDA/APHIS/Wildlife Services, National Wildlife Research Center
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The Wildlife Damage Management Working Group of The Wildlife Society

The Second National Invasive Rodent Summit held on October 19-21, 2004, at the National Wildlife Research Center (NWRC) in Fort Collins, CO, was a follow-up to the "Rat Summit" held in San Francisco, CA, in 2001. Like the first "Rat Summit," this conference emphasized the management of rodents to conserve plants, other wildlife and habitats. Presentations also highlighted the importance of rodent predators as part of a successful integrated pest management strategy. The 105 attendees were from 10 countries and territories and 23 states. Attendees included scientists and managers from government and private sector land and resource management agencies and groups. Special sessions covered nutria management, rodenticide risk assessment techniques, rodent eradication efforts on islands, rodent control in mainland habitats, and the role of rodents in disease transmission. A member of the executive committee of the National Invasive Species Council made a plenary presentation and the keynote talk was provided by Dr. William B. Jackson of Bowling Green State University on "A Century of Rat Control." The comments and evaluation forms from attendees suggest that the Invasive Rodent Summit was a huge success.

Papers (abstracts follow)

- Historical perspectives and current ecological impacts of nutria in Louisiana
- Urban desert islands
- Flea control on wild rodents
- An overview of rodent control to protect biodiversity on mainland New Zealand
- Risk assessment of rodenticide use in New Zealand
- Rodents on oceanic islands
- Invasive species

- Improving the management of rat control damage on the Caribbean National Forest
- The USGS role in nutria research and management
- Controlling roof rats (Rattus rattus) for protection of Puerto Rican parrots
- Anticoagulant resistance in farm rat populations in the UK
- Invasive rodent research priorities in New Zealand
- The National Invasive Species Council
- Integrated Pest Management in the U.S. National Park Service and the U.S. Fish and Wildlife Service
- Addressing the invasive rodent issue on Alaska Maritime National Wildlife Refuge
- Planning for eradication of Arctic ground squirrels on selected islands within the Alaska Maritime National Wildlife Refuge
- Department of Defense rodent control
- Registration status of two anticoagulant products for eradicating rodents from islands and derelict vessels
- Using a general indexing paradigm to monitor rodent populations
- EPA's comparative ecological risk assessment of nine rodenticides
- Anticoagulant residues in rat liver: persistence and secondary hazard to nontarget species
- Overview of rodent-borne diseases
- Probabilistic risk assessment model for predators and scavengers exposed indirectly to a commensal rodenticide
- Virus-vectored fertility control in house mice
- Island conservation in the U.S. Channel Islands National Park
- A century of rodent control
- Pesticide registration requirements in the U.S. with emphasis on options for controlling invasive rodents
- Probabilistic risk assessment model for determination of nontarget risks to birds in diphacinone baited areas on Hawaii
- Development of nutria eradication strategies for Chesapeake Bay marshlands
- Louisiana coast-wide nutria control program: year two

- Towards a risk assessment of second generation rodenticides
- Rodent declines and invasions in the Florida Keys
- An overview of rodent contraceptive development at the USDA/APHIS Wildlife Services National Wildlife Research Center
- Assessing potential of applying baits on native marshes to reduce nutria impacts
- Invasive species research at the USDA National Wildlife Research Center, Hilo Field Station
- Accidental discharge of brodifacoum baits in a tidal marine environment
- Managing roof rats (Rattus rattus) to reduce their impact on open-cup nesting songbirds in riparian forests of the Central Valley, California
- Chlorophacinone baiting for Belding's ground squirrel
- Elevated bait station trials (and tribulations) in crab country
- Registration costs of new products and new use
- Hantaviruses in the western hemisphere: a review
- Sero-survey for antibodies to flaviviruses in wild mammals in central and eastern United States
- Rodent control techniques: can we learn from agricultural uses
- Benefit/cost analysis of rodent control for conservation
- Preventing rat introductions to the Pribilof Islands, Alaska, USA
- Preventing rat spills on U.S. Alaska Maritime National Wildlife Refuge
- Developing a rat-IPM technology for the Philippine irrigated rice lowland ecosystem
- The eradication of introduced rats on the U.S. Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands
- Leptospirosis in the Azores: the rodent connection
- Are both rat species, Rattus rattus and R. norvegicus, omnivorous?

ABSTRACTS (alphabetical by presenter, in bold)

John Baroch, Genesis Laboratories, Inc., P.O. Box 1149, Wellington, CO 80549 USA

Historical Perspectives and Current Ecological Impacts of Nutria in Louisiana

The nutria or coypu *(Myocastor coypus)* is a rodent native to South America that has been introduced almost worldwide since the early 1900's, originally with the intent of fur farming in many cases. The nutria is a large (over 6 kg), semi-aquatic rodent with a voracious appetite and high reproductive potential. Nutria became established in the Louisiana wetlands in the 1930's. The habitat proved to be ideal and populations exploded, reaching an estimated 20 million animals in less than 20 years. Trapping of nutria for their pelts formed the backbone of the Louisiana fur trade from the 1960's until the early 1980's when prices for furs on the world market and in Louisiana plummeted. Since then the annual trapping harvest, which was over one million animals per year for many years, has dwindled to 29,544 in the 2000-2001 season and nutria numbers have increased dramatically. Reports of nutria damage to wetland habitats emerged in the late 1980's. Numerous studies of the wetland environments of Louisiana since then have documented the deleterious effects nutria over-grazing can have on the habitat. Ecologically, nutria are an important prey item for the alligator, but effects of nutria activity on other animals are primarily negative. Their most important impact is habitat modification and in many cases, habitat destruction. When impacts of intense nutria herbivory are added to the abiotic forces that are degrading the Louisiana coastal marshes the potential for lasting loss of wetland area is magnified. This presentation reviews the chronology of nutria establishment in Louisiana and historic population trends; interaction of nutria with other animals in the coastal marshes, and impacts of nutria herbivory on the wetland plant communities.

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Urban Desert Islands: Can They Support an Invasion of Roof Rats?

Unsuccessful outbreaks of roof rats (*Rattus rattus*) have occurred in Arizona since the late 1800s. During 2001, the Maricopa County Environmental Services Department verified the latest outbreak in Phoenix, Arizona. Although the desert surrounding Phoenix is formidable to roof rats, residential and urban development has probably sufficiently altered habitat to render it habitable for roof rats. Ongoing community and government campaigns are reducing resources necessary for rat survival and are working to suppress rat populations. Whether these efforts will be adequate to eradicate roof rats from the area is unknown. Rat activity has declined over the last several months. However, it is difficult to assess whether this reduced activity reflects decreased rat numbers or if rats have become less active during the summer heat.

Jeff N. Borchert, Genesis Laboratories, Inc., P.O. Box 1149, Wellington, CO 80549 USA

Flea Control on Wild Rodents

The control of plague has historically focused on the control of the rodent host and its associated fleas. Currently, the most common method of flea control on wild rodents is performed by the use of insecticidal dusts placed at the mouth of burrow. Genesis Laboratories evaluated systemic insecticides added to rodent baits for their potential to control the fleas of rodents. This talk summarizes these laboratory evaluations of insecticides. In the future, host targeted systemic insecticides of this nature incorporated into rodent baits offer a possible means of flea control on wild rodents.

Keith Broome, New Zealand Department of Conservation, PO Box 112, Hamilton, New Zealand

An Overview of Rodent Control to Protect Biodiversity on Mainland New Zealand

NZ has some of the world's longest lists of human induced extinctions and threatened species due to habitat loss and a range of invasive pests. We consider mainland NZ as the two largest islands 'North' & 'South' where three rat and one mouse species exist. Rodents are ubiquitous in most mainland habitats with ship rats (*Rattus rattus*) and mice (*Mus musculus*) most important today. Other species (*R. norvegicus, R. exulans*) were historically significant in their impact and continue to be dominant on some smaller islands where one or more species are absent. Complex and dynamic predator-prey relationships exist and the full impact of rodent introductions is yet to come. Mainland rodent control strategies usually set management targets of low ship rat densities over bird breeding seasons and must be integrated with other pest control. Recently we have accepted the new challenge of managing the impacts of episodic irruptions of rodents threatening critically endangered species. Techniques include a range of pesticides and kill traps. Success at small and medium scales from well planned and supported programmes has drastically improved the status of some threatened species and increased bird populations generally at those sites. Many challenges exist to sustaining these successes, increasing the scale, and providing year-round protection to more vulnerable fauna. Some novel strategies are emerging to meet these challenges as well as continued refinement of existing techniques and research to grow our understanding of the issues.

Keith Broome, New Zealand Department of Conservation, PO Box 112, Hamilton, New Zealand; Penny Fisher, Landcare Research, PO Box 69, Lincoln, New Zealand

Risk Assessment of Rodenticide Use in New Zealand: An Overview

Broad-scale field application of vertebrate pesticides in NZ is internationally conspicuous. However the risks of such activities are not taken lightly. Use patterns reflect a balance between managing the severe impacts of invasive species on unique biodiversity and agricultural values, and the adverse effects of management techniques. An ongoing and rigorous regulatory framework governing the use of hazardous substances, including vertebrate pesticides, has recently been upgraded. The multi-tiered system identifies and manages risks from manufacture to disposal. Two Central Government bodies are involved in authorising products for sale in NZ. The Environmental Risk Management Authority focuses on environmental risks of all hazardous substances and new organisms. Their risk assessment approach uses recognised (Global Harmonisation) criteria, classifying substances and applying risk management controls. The Agricultural Compounds & Veterinary Medicines group of the NZ Food Safety Authority is focused on food residue risks, export food quality and animal welfare risks. Again the assessment process uses risk classification to trigger management controls. Any vertebrate pesticide on the market will be authorised by these two agencies and carry mandatory controls to manage their designated risk areas. Regional Government and Health authorities play a part in authorising field use of these products, sometimes case by case using information from an assessment of environmental effects. Such permissions typically come with risk management and environmental monitoring controls. For less hazardous products or methods, general permission is granted for specified activities subject to standard controls stated in Regional plans. In addition to these regulatory systems, the Department of Conservation (DOC) has a risk assessment process to further support safe field use of vertebrate pesticides on public conservation land. This system considers a range of risk categories and pragmatically scores both risk and uncertainty for each against a consistent framework. Risk scores exceeding thresholds generate controls or may prohibit use on land administered by DOC. High uncertainty scores demand further information gathering. Permission to use pesticides on public conservation land is always on a case by case basis, often requiring an assessment of environmental effects. Authorising managers use the DOC risk assessment as a platform and add any further controls necessary to manage risks associated with particular sites.

Alan Buckle, University of Reading, Wendlesworth, Elsted Road, South Harting, Petersfield, Hampshire, GU31 5LR United Kingdom

Rodents on Oceanic Islands: Impacts and Management

Since the earliest days of exploration humans have accidentally, and sometimes purposefully, introduced rodents (mainly Norway rats, *Rattus norvegicus*; ship or black rats, *Rattus rattus,* and Polynesian rats, *Rattus exulans*) to places where they have landed and colonised. On the islands, the rodents preyed upon species poorly adapted to withstand their depredations. The full extent of this disaster on the biodiversity of the world's oceanic islands will never be known but in two recent cases, Lord Howe Island and Big South Cape Island, ornithologists were able to record the rodents' catastrophic impact on the islands' avifauna. Many species were extinguished and populations of others decreased dramatically. Thanks to the development of a range of management techniques, mainly pioneered by workers from New Zealand, conservationists now have an ability either to remove alien rodents from islands or, if this is impractical, to control rodents in particularly sensitive areas to allow endangered species a chance to recover.

Zino's Petrel breeds in burrows on cliff ledges among the peaks of Madeira's central mountain range. During the mid-1980s, it was found that the birds had failed to breed successfully for several years and that rats, coming up from the forests below, had infested the breeding ledges. The site was surveyed and, after detailed planning which included environmental impact assessment, a rodent control programme was initiated to protect the birds. This involved the placement of specially-designed rodenticide bait boxes, both in a 'cordon sanitaire' around the breeding ledges and on the ledges themselves. The difficult work of maintaining this programme has continued every year since thanks to the efforts of the Freira Conservation Project and the Natural Park of Madeira. Breeding was at first slow to re-establish but has improved in recent years, with a record in 2003 when over 20 chicks fledged.

Different problems faced the workers of the Natural Park of Madeira on Great Salvage Island, 160 nautical miles south of the Madeira mainland. The island was overrun with rabbits (*Oryctolagus cuniculi*) and house mice (*Mus* spp.). A project was initiated in 2002, aimed at the complete eradication of these species from the 240-ha island, in order to protect breeding seabirds. The island is a breeding station for globally important colonies of the White-faced Storm-petrel (*Pelagodroma marina*), Madeiran Storm-petrel (*Oceanodroma castro*), Bulwer's Petrel (*Bulweria bulwerii*), Little Shearwater (*Puffinus assimilis*) and Cory's Shearwater (*Calonectris diomedia*). Once again, severe difficulties of planning and logistics were overcome to establish and maintain a grid of rodenticide baiting stations over the entire island for more than a year. The rabbits were quickly removed and careful surveys in November 2003 failed to discover any signs of mice. The final outcome of the project, which also involved scientists from the UK Forestry Commission and the University of Reading, is eagerly awaited.

Earl Campbell, USDI Fish and Wildlife Service, PO Box 50088, Honolulu, HI 96850 USA

Invasive Species: Bringing it Down to Rodents

Issues related to invasive species control in the North America are not a new topic. Man has been introducing species to this continent as pathways and rates of introduction have increased over time. Among vertebrates, the historic introduction of new rodent species within the United States and to its insular Territories and Possessions has had significant effects on human health, agriculture, and natural resources. Rodent control has traditionally focused on human health and agricultural issues, but in recent years, tools for rodent control have been applied in conservation situations. This presentation is intended to give background information to participants of the conference on current issues related to the control on non-native rodents in the United States. It is intended to link background information with new ideas and efforts that will be themes of this meeting and, finally, it will suggest new directions that may assist in the management of introduced rodents.

Felipe Cano, USDA Caribbean National Forest, HC01 PO Box 13490, Rio Grande 00745-9625 Puerto Rico

Improving the Management of Rat Control Damage on the Caribbean National Forest

The USDA Caribbean National Forest (CNF) in Puerto Rico contains world-class resources set in the only tropical rainforest in the U.S. National Forest System. The CNF contains five endangered species including one of the ten most endangered birds in the world: the Puerto Rican Parrot (*Amazona vittata*). During the past 3 years the CNF has collaborated with USDA/APHIS Wildlife Services to reduce the impacts from two species of exotic rats. Since then research has been conducted by Dr. Desley Whisson and Ms. Jessica Quinn (University of California, Davis) in exotic species movements and control. The collaborative effort has provided the CNF with a more scientific and responsive exotic species control program. **[POSTER]**

Jacoby Carter, USGS National Wetlands Research Center, 700 Cajundome Blvd., Lafayette, LA 70506 USA

The USGS Role in Nutria Research and Management

The USGS has been involved in nutria research for over 10 years. In the past studies focused on demonstrating and quantifying nutria contribution to marsh loss and post nutria marsh recovery, documenting life history parameters such as dispersal and survivorship and the development of quantitative models. Many of these projects have continued into the present. However, the USGS has developed new two new areas of research emphasis: population genetics and the development of new techniques for estimation of population and following nutria movement. The USGS has played an important role in coordinating nutria research and fostering communication between the research and management communities.

Desley Whisson, Department of Wildlife, Fish and Conservation Biology, University of California, One Shields Ave, Davis, CA 95616 USA; **Bernice Constantin,** USDA/APHIS, Wildlife Services, 2820 E. University Ave. Gainesville, FL 32641 USA; Richard Engeman, USDA/APHIS National Wildlife Research Center, 4101 Laporte Ave, Fort Collins, CO 80521-2154 USA; Felipe Cano, USDA Caribbean National Forest, HC01 PO Box 13490, Rio Grande 00745-9625 Puerto Rico

Controlling Roof Rats (*Rattus rattus*) for Protection of Puerto Rican Parrots

Roof rats (*Rattus rattus*) are common throughout the USDA Caribbean National Forest (CNF), Puerto Rico, with trap success as high as 64% recorded in some locations. Consequently, rats pose a significant threat to nesting Puerto Rican Parrots (*Amazona vittata*), one of the ten most endangered birds in the world. Until recently, rat control at parrot nest trees in the CNF involved placing one or 2 bait stations containing 0.005% diphacinone bait near the base of the tree. This strategy has likely had little impact on rat populations and their activities at parrot nests. Furthermore, evidence of rats inside failed nests confirms the need for a more effective rat control strategy. In 2002, we conducted a study to determine the effectiveness and cost of implementing a more intensive baiting strategy around known nest trees immediately prior to and during the parrot nesting period. We monitored radio-collared rats and recorded bait consumption from bait stations to determine the effectiveness of a grid of 18 bait stations containing 0.005% diphacinone bait spaced at 40-m intervals and centered on the nest tree. All radio-collared rats were dead within 2 weeks and trap success was extremely low after a 3-week baiting period. The baiting strategy was therefore implemented at other nest trees where rats had been identified as a potential cause of unsuccessful nesting attempts in the past. Fledging rates were higher in 2003 than in previous years with no nest failures attributed to rats. Our study indicates that rat control is a highly cost-effective tool to apply in the Puerto Rican parrot recovery program.

Dave Cowan, Ged Kerins, Mark Lambert, Alan Macnicoll and Roger Quy, Central Science Laboratory, Sand Hutton, York YO41 1LZ United Kingdom

Anticoagulant Resistance in Farm Rat Populations in the UK: Implications for Management and Environmental Impact

The opportunistic and invasive Norway rat (*Rattus norvegicus*) thrives in and around farm buildings in the UK. Consequent damage to stored food, damage to structures and zoonotic disease risks necessitates management action. The main management tools are rodenticide baits with anticoagulant use becoming the first, last and only resort for many. The extensive use of such materials has driven selection favouring physiological resistance. Surveys of farm rat populations have revealed widespread resistance to warfarin, and by inference other first-generation anticoagulants. Warfarin-resistant rats are essentially warfarin "proof" in that they are unlikely to be able to eat sufficient bait to ingest a lethal dose of under field conditions. Reports of resistance to second-generation anticoagulants arose shortly after their introduction in the 1970s. Initially this reflected only low-degree resistance where, under favourable field conditions, resistant animals might reasonably be expected to ingest a lethal dose. In recent years, however, populations have been identified with high prevalence of high-degree resistance to one or more second-generation anticoagulants. Here we report on the responses of such populations to the use of second-generation anticoagulant and non-anticoagulant rodenticides. In particular, we focus on the resistance status of populations as they recover from control, which we interpret in terms of the expression of pleiotropic costs, notably a raised requirement for vitamin K and reduced growth rate. Such costs may constrain the spread of resistance. There is, however, some evidence that such costs may no longer be associated with certain resistant traits. This has important implications for the long-term management of populations with high resistance prevalence and the environmental safety of rodenticide use against such populations.

Phil Cowan, Landcare Research, Private Bag 11052, Palmerston North, New Zealand
[Presented by Penny Fisher]

Invasive Rodent Research Priorities in New Zealand

New Zealand has no native rodents but 4 introduced species, *Rattus norvegicus*, *R. rattus*, *R. exulans* and *Mus musculus*. R. exulans (kiore) was introduced by the original Maori settlers whereas the others were brought by European migrants in the 19th century. Rodent problems in urban areas and in crops are largely of nuisance value, but the suite of introduced rodents is a major threat to New Zealand's indigenous biota. They prey on native birds and invertebrates, impact on forest processes through seed predation, and are primary prey for introduced carnivores, such as stoats, ferrets and feral cats, that also are significant predators of native animals.

A recent meeting of researchers and management agencies identified priorities for research on biology and control of rodents in New Zealand, including eradication of rodents from offshore islands. Priorities for research on the ecological role of rodents and their impacts, and rodent control strategies and tactics will be presented, and the concept of a rodent pest network discussed.

Chris P. Dionigi, USDI, OS,SIO/NISC, 1849 C Street, NW, Washington D.C. 20240 USA

The National Invasive Species Council: An Update

In 1999, the National Invasive Species Council (NISC) was established by the U.S. Presidential Executive Order 13112. The NISC helps ensure that federal invasive species activities are coordinated and complementary. The NISC is co-chaired by the U.S. Secretaries of Agriculture, Interior, and Commerce and includes the Secretaries of Transportation, Homeland Security, State, Defense, Treasury, Health and Human Services, the Administrator of the U.S. Environmental Protection Agency, and the Director of the U.S. Agency for International Development. Invasive species harm the economy, the environment and sometimes, animal and human health. They can be found in every region in the U.S. and around the world. The Asian longhorn beetle, sudden oak death, and emerald ash borer have the potential to destroy entire forest ecosystems. Other examples include the now infamous snakehead fish, zebra mussel, brown tree snake, Asian carp, yellow star thistle, tamarisk, nutria and pathogens such as West Nile virus. Invasive species are the second leading cause--after habitat loss--of species being listed as endangered or threatened. They do not respect borders and cause severe problems that are local, regional, national and global in scope. Problems associated with invasive species are accelerating due to increases in trade, travel and tourism. In the U.S., it is estimated that invasive species cost the U.S. economy about $100 billion per year.

Carol DiSalvo, Biological Resources Management Division, National Park Service, 1201 I (eye) Street, NW, Washington, D.C. 20005 USA; **Linda Lyon**, National Wildlife Refuge System, U.S. Fish and Wildlife Service, 4401 N. Fairfax Dr., Arlington, VA 22203 USA

Integrated Pest Management in the U.S. National Park Service and U.S. Fish and Wildlife Service

The National Park Service (NPS) and Fish and Wildlife Service (FWS) are resource management agencies in the Department of the Interior (DOI). We have numerous needs for managing rodents on our lands including endangered species protection, eradication of invasive species, human health, concessionaires, and building maintenance. Management of pests by NPS and FWS is guided by DOI and agency policies. We briefly will review these policies as they relate to rodents and discuss the basic 11-step approach to integrated pest management in NPS and FWS.

Peter Dunlevy, USDI/FWS Alaska Maritime NWR, 95 Sterling Highway, Suite 1, Homer, AK 99603-7473 USA

Addressing the Invasive Rodent Issue on Alaska Maritime National Wildlife Refuge

A program has been initiated on the U.S. Alaska Maritime NWR to address the serious threat invasive rodents pose to the important natural resources on the Refuge. The program is designed to accomplish the necessary planning, surveys, prevention measures, studies and outreach that will set the stage for a comprehensive Invasive Rodent Program on the Refuge for the next 20-30 years. The primary purpose of the program is to restore and conserve native ecosystems on Alaska Maritime NWR by preventing further introductions of invasive rodents and by removing invasive rodents from Refuge islands where they have become established.

Major elements include: National Environmental Policy Act (NEPA) compliance, appropriate federal and state rodenticide registrations, inventory invasive rodents within the Refuge, invasive rodent quarantine measures, test eradication and monitoring methods, assess nontarget hazards, document recovery and public outreach. This presentation will describe the program and planning as well as briefly highlight accomplishments to date.

Steve Ebbert, USDI/FWS Alaska Maritime NWR, 95 Sterling Highway, Suite 1, Homer, AK 99603-7473 USA

Planning for Eradication of Arctic Ground Squirrels on Selected Islands within the Alaska Maritime National Wildlife Refuge

The U.S. Alaska Maritime National Wildlife Refuge has successfully eradicated non-native foxes from over 40 islands, cattle from two islands, and reindeer from one island. Planning for invasive rodent eradication began on the refuge began in 2002 with emphasis on Norway rats. Arctic ground squirrels (another invasive rodent) are established on about one dozen smaller refuge islands. Currently there are no toxicants registered for use against arctic ground squirrels in Alaska. The refuge is in initial stages in planning for ground squirrel eradication. Potential eradication strategies for this project will be presented.

Peter J. Egan, Armed Forces Pest Management Board, Forest Glen Section – WRAMC, Washington, D.C. 20307-5001 USA

Department of Defense (DoD) Rodent Control

Historically DoD has controlled rodent pests to protect human health, food, and fiber. Rodents have assumed a different role in recent years as a food resource for brown tree snakes and as predators on endangered species. Prey reduction and protection of endangered species will require new tools for controlling these emerging problems.

John D. Eisemann, USDA/APHIS Wildlife Services, National Wildlife Research Center, 4101 Laporte Avenue, Fort Collins, CO 80521-2154 USA

Registration Status of Two Anticoagulant Products for Eradicating Rodents from Islands and Derelict Vessels

In 2001, the USDI Fish and Wildlife Service entered into a cooperative agreement with the National Wildlife Research Center (NWRC) to work towards securing two rodenticide registrations from the U.S. Environmental Protection Agency for eradicating invasive rodents from islands and derelict vessels. Pesticide registration staff from the NWRC are been working with two private pesticide manufacturers to obtain registrations for brodifacoum and diphacinone products. The intent of these rodenticide registrations is to rid islands of introduced rodent predators for the protection of native flora and fauna. Additionally, the project aims at stopping new rodent invasions potentially arising when ships ground on islands. Since eradication is the goal of predator control on islands, the labels are written with enough flexibility to provide the maximum chance of total eradication. As proposed, these registrations would allow rodenticide application by aerial and hand broadcast methods or through the use of bait stations, burrow baiting or canopy baiting. The registration applications for these products are expected to be submitted to the U.S. EPA prior to the 2nd National Invasive Rodent Summit.

Richard Engeman, USDA/APHIS, Wildlife Services, National Wildlife Research Center, 4101 Laporte Ave, Fort Collins, CO 80521-2154 USA; Desley Whisson, Department of Wildlife, Fish and Conservation Biology, University of California, One Shields Ave, Davis, CA 95616 USA (present address: DEH, Regional Conservation Conservation Programs Unit, PO Box 39, Kingscote, SA 5223, Australia)

Using a General Indexing Paradigm to Monitor Rodent Populations

Population monitoring is a valuable component to managing invasive rodent populations. Indices can be efficient methods for monitoring rodent populations when more labor intensive density estimation procedures are impractical or invalid to apply, and many monitoring objectives can be couched in an indexing framework. Indexing procedures obtain maximal utility if they exhibit key characteristics, including being practical to apply, being sensitive to changes or differences in the target species= population, having an inherent variance formula and allowing for precision in index values, and relying on as few assumptions as possible. Here, a general indexing paradigm that promotes the characteristics that make indices most useful is specifically applied for rodent monitoring scenarios. Observations are made at stations located throughout the area of interest. Stations can take many forms, depending on the observations, and range from points for visual counts to tracking plots (or tiles), bait blocks, chew cards, trap lines and many others. A wide variety of observation methods for many animal species can fit into this format. Observations are made at each station on multiple occasions for each indexing session. Geographic location data for each station are encouraged to be collected. No assumptions of independence are made among stations, nor among observation occasions. Measurements made at each station are required to be continuous or unboundedly discrete. The formula for a general index to describe population levels is presented along with a derived variance formula. Issues relevant to the application of this methodology to rodent populations, and indices in general, are discussed.

William Erickson, U.S. EPA Office of Pesticide Programs, Environmental Fate and Effects Division, 1200 Pennsylvania Avenue, NW, Washington D.C. 20460 USA

EPA's Comparative Risk Assessment for Nine Rodenticides

As part of the reregistration of pesticides mandated by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), U.S. EPA's Office of Pesticide Programs (OPP) conducted a comparative risk assessment for nine rodenticides that pose potential risks to birds and nontarget mammals. The rodenticides include 3 second-generation anticoagulants (brodifacoum, difethialone, bromadiolone), 3 first-generation anticoagulants (diphacinone, chlorophacinone, warfarin), and 3 non-anticoagulant compounds (zinc phosphide, bromethalin, cholecalciferol). These rodenticides are used predominantly to control commensal rats and mice in and around buildings; some also have field uses. Rodenticide food baits are not selective to the target species, and birds and nontarget mammals attracted to grain-based or other food baits are at risk. Information from laboratory and pen studies, field studies and control programs, incident reports, and toxicokinetic studies also indicates that avian and mammalian predators and scavengers can be at risk from consuming target and nontarget animals poisoned with some of these rodenticides. Because exposure and effects data are limited or are not easily expressed in quantitative terms, a lines-of-evidence approach and a comparative analysis model are used to categorize risk rankings for primary risks to birds and nontarget mammals and secondary risks to avian and mammalian predators and scavengers. This approach to evaluating risks complies with EPA's Guidelines for Ecological Risk Assessment.

The highly persistent, single-feeding second-generation anticoagulants stand out as the rodenticides posing the greatest overall risks to nontarget species. More than 250 incidents, mostly with brodifacoum, attest that exposure occurs to owls, hawks, eagles, corvids, foxes (including endangered kit foxes), coyotes, and others. First-generation anticoagulants are less persistent and appear to pose considerably less risk to birds, although primary and secondary risks to mammals exceed the Agency's Levels of Concern. The non-anticoagulants pose primary risks to birds and nontarget mammals; they appear to pose minimal secondary risks, but confirmatory data are needed for bromethalin and cholecalciferol. Risk presumptions are based on a deterministic approach,

and many uncertainties exist. Refining the assessment to establish a quantitative measure of likelihood of exposure and effects would require a much more extensive data set than is currently available. Such information includes spatial/temporal data on quantities of bait applied and baiting practices, including use of bait stations and indoor versus outdoor applications for each target species; primary and secondary hazards data for focal species; sublethal effects on behavior and reproduction; diet and foraging behavior of predators and their opportunism in exploiting poisoned rodents and birds; behavior of poisoned rodents; residues in target and nontarget consumers before and after death; and numerous others. Better monitoring and incident reporting also is essential.

Penny Fisher, C.E. O'Connor and C.T. Eason, Manaaki Whenua – Landcare Research, PO Box 69, Lincoln New Zealand

Anticoagulant Residues in Rat Liver: Persistence and Secondary Hazard to Non-target Species

In New Zealand, the second-generation anticoagulant brodifacoum has been successfully used in island rodent eradications and is currently applied in some mainland areas to control introduced pests such as brushtail possums (*Trichosurus vulpecula*) and rodents (*Rattus* spp.). However, ongoing field use of brodifacoum is under scrutiny because nontarget wildlife can acquire persistent residues. To investigate alternative rodenticides, the persistence of sublethal oral doses of five anticoagulants (brodifacoum, warfarin, pindone, diphacinone and coumatetralyl) in laboratory rats was compared. Diphacinone and pindone had the shortest hepatic half-lives, indicating a shorter-term secondary hazard. A further study compared concentrations of liver residues of the five anticoagulants in laboratory rats after different regimes of bait consumption. These data, alongside available toxicity values, were used to construct a theoretical, conservative assessment of the risk of acute secondary poisoning to New Zealand nontarget birds and mammals. Taking account of persistence, acute toxicity and residue concentrations in rats, brodifacoum presented the overall highest secondary risk and diphacinone the overall lowest. However, warfarin presented a very low risk to birds, and medium risk to mammals. Coumatetralyl was the most persistent of the first-generation anticoagulants studied, but a very low risk to birds and medium risk to mammals was indicated. Pindone had a short persistence like diphacinone, but had a high risk to birds and a medium risk to mammals. Diphacinone especially, but also coumatetralyl and warfarin, should be further evaluated in field studies as alternative rodenticides for use in New Zealand.

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An Overview of Rodent-borne Diseases

Interest in rodent-associated zoonotic diseases has increased during recent years as a result of high profile outbreaks involving well-known rodent-associated disease agents (plague and tularemia), the sudden appearance of unexplained illnesses caused by previously unrecognized rodent-associated pathogens (Lyme disease and Hantavirus Pulmonary Syndrome), the introduction of exotic disease agents into native host populations (monkeypox virus in pet prairie dogs and humans), or the fears that some of these agents, especially plague or tularemia, might be used as weapons of bioterrorism. This presentation briefly reviews the status of the above diseases and their etiologic agents. Also discussed are current concerns about their spread and control.

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Probabilistic Risk Assessment Model for Predators and Scavengers Exposed Indirectly to a Rodenticide

A probabilistic model is described for estimating the risk to predators and scavengers from indirect exposure to a rodenticide. The model combines predictions of dietary exposure with information about toxicological effects to estimate the likelihood that an individual predator or scavenger will accumulate a lethal dose. The exposure model is a probabilistic implementation of a standard dietary dose model based on food ingestion rate, percentage rodents in the diet, percentage of rodents that have been exposed to a rodenticide baiting program, and concentration of rodenticide in exposed rodents. Data on some of the model parameters (especially dietary composition and rodenticide concentrations in rodents) are available from field studies, while other parameters are based on expert opinion or assumptions. The model generates exposure probability curves for individuals, and also simulates variability among individuals. Effects of rodenticide exposure are estimated from laboratory studies with birds and mammals. A Bayesian hierarchical approach combines raw data from all studies into calculated dose-response relationships for individual species, or for species of unknown sensitivity. The exposure probability curves and dose-response curves are integrated into curves depicting the likelihood of lethal poisoning of an individual predator or scavenger. The model is illustrated using the coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), red fox (*Vulpes vulpes*), great-horned owl (*Bubo virginianus*), and red-tailed hawk (*Buteo jamaicensis*) as the focal species. Through selection of distributions or assumptions for model parameters, the model can be used to explore a range of exposure scenarios and rodenticide baiting practices.

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Virus-vectored Fertility Control for House Mouse (*Mus domesticus*) in Australia

House mouse populations erupt irregularly in the grain growing regions of south-eastern Australia, reaching densities greater than 1000 mice per hectare and causing major economic impacts within rural communities. Current control strategies usually involve the use of rodenticides (e.g. zinc phosphide), which are not target specific, are costly to apply, can lead to environmental damage and their humaneness is being questioned.

As an alternative to current lethal agents, fertility control approaches whereby viruses are being assessed as delivery vectors are being developed. The research program combines molecular biology, population ecology and epidemiology of the virus vector as well as risk assessment of the use of genetically engineered organisms in the Australian landscape.

An ideal immunocontraceptive vaccine must induce a sustained immune response which blocks a key reproductive process (e.g. ovulation or fertilization), be species-specific, be delivered effectively throughout the pest population on a broad scale, be cost-effective, environmentally benign and publicly acceptable – a big challenge. The components of the fertility control approach for the wild house mouse comprise mouse zona pellucida protein C (mZP3) and mouse cytomegalovirus (MCMV). MCMV has been chosen as the candidate delivery vector for a number of reasons. Importantly the virus is present at high prevalence in wild mice in Australia, and it is species-specific. The virus spreads between mice by close contact, and mice can become infected with multiple strains, which means that super-infection with a recombinant virus is feasible. The virus persists in the salivary gland and lung and can be reactivated during periods of stress (e.g. social interactions). As a DNA virus it can be engineered to carry additional genetic information.

In the laboratory we have successfully tested the effects of infection of mice with an engineered Australian strain of MCMV expressing the mZP3 gene (recMCMV-mZP3). Infection with the recombinant virus results in the stimulation of the host immune system – antibodies to both the virus and mouse ZP3 are produced. The mice are infertile for approximately 250 days. Infertility appears to be due to complete loss of primordial follicles within the ovaries of infected mice indicating that sterility is permanent and irreversible. A major challenge being addressed in current experiments is whether the vaccine transmits between mice and continues to induce infertility.

Field and laboratory results so far, as well as computer modelling, indicate excellent prospects for the use of viral vectored vaccines based on MCMV for managing eruptions of mouse populations. However, the public acceptability of the technology is yet to be confirmed. The issues of species specificity, delivery system stability and other potential or perceived risks require open and wide-ranging debate, nationally and internationally, before trial field experiments of a genetically modified virus for controlling field populations of mammals could occur.

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Island Conservation in the U.S. Channel Islands National Park: Rat Eradication from Anacapa Island

The ability to eradicate rats from islands is one of the most powerful tools available to prevent extinctions. This tool has been underutilized in North America where the relatively few eradications have utilized bait stations alone. On many islands, bait stations alone cannot be used due to steep topography or sensitive species. Anacapa Island (a steep and rugged 296 ha island consisting of three distinct islets) had introduced *Rattus rattus* that threatened native species, including an endemic deer mouse (*Peromyscus maniculatus anacapae*). Consequently, aerial broadcast was the only feasible method to eradicate rats. After 2 years of planning, testing and monitoring, a 25 ppm brodifacoum bait was aerially broadcast onto East Anacapa in December 2001, and onto Middle and West Anacapa Island in November 2002. We protected the endemic mouse by staggering the eradication so that a free ranging population always existed on one or more islets. In addition, we maintained a captive population on island followed by a soft release and subsequent monitoring to ensure viability. This was the first aerial application of rodenticide to eradicate rats in North America, and the first on an island with an endemic rodent. The legal and public scrutiny and the complex environmental compliance process required extensive mitigation to minimize primary and secondary risks to birds, and reduce potential bait drift into the marine ecosystem. Hopefully, the success of this project will facilitate future rat eradications in North America.

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A Century of Rodent Control

There has been a long history of development and testing of methods for rodent control, including traps, toxicants, and delivery systems. A wide array of tools and techniques has been available for managing rodents, however, changing social dynamics and the emergence of the animal rights movement have led to increasing restriction or elimination of many of the traditional strategies or materials used by wildlife managers and pest management specialists. This has created a demand for new approaches to rodent damage management. The challenge to wildlife scientists is to provide data to maintain the broadest array of appropriate, science-based techniques and management options, while fostering the rapid development and application of new technology.

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Pesticide Registration Requirements in the U.S. with Emphasis on Options for Controlling Invasive Rodents

This presentation discusses U.S. regulatory options and registration requirements for pesticide products such as might be used to control invasive rodents that threaten the viability of populations of native species. The regulatory options are: a full Federal registration under §3 of the Federal Insecticide Fungicide and Rodenticide Act (FIFRA), a "special local needs" registration under §24(c) of FIFRA to allow use of the pesticide in the State where the problem occurs, an experimental use permit under §5 of FIFRA to authorize research related to the problem at hand, an emergency exemption from some or all of the requirements of FIFRA (as authorized under §18), or a determination under §25(b) of FIFRA that the selected pesticide is of a character such as not to require regulation under FIFRA. The paper discusses the requirements for and the advantages and disadvantages of each of these regulatory options.

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Probabilistic Risk Assessment Model for Determination of Non-target Risks to Birds in Diphacinone Rodenticide Baited Areas on Hawaii

Three probabilistic models were developed for characterizing the risk of mortality and subacute coagulopathy to Po'ouli, an endangered non-target avian species, in broadcast diphacinone baited areas on Hawaii. For single day exposure, the risk of Po'ouli mortality approaches 0. For 5 day exposure, the mean probability of mortality increased to 3% for adult and 6% for juvenile Po'ouli populations. For Po'ouli which consume snails containing diphacinone residues for 14 days, the model predicted increased levels of coagulopathy for 2.4% and 4.0% of adult and juvenile Po'ouli populations, respectively. Worst case deterministic risk characterizations predicted acceptable levels of risk for non-threatened or endangered species such as northern bobwhite quail and mallards.

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Development of Nutria Eradication Strategies for Chesapeake Bay Marshlands

Non-native nutria (*Myocastor coypus*) have been linked to the destruction of more than 8,000 acres of marshlands at the Blackwater Unit of the Chesapeake Marshlands National Wildlife Refuge Complex. Feral populations were first established in the 1940's in Dorchester County, Maryland, and populations have since expanded throughout the Delmarva Peninsula, threatening marsh habitats throughout the Chesapeake Bay watershed. We describe ongoing efforts to eradicate this invasive species from Chesapeake Bay marshlands. Traditional harvest techniques, including trapping and hunting, are being applied within an Integrated Wildlife Damage Management framework in order to achieve a systematic and progressive removal of nutria from discreet units of marsh habitat. To date, 8,000 nutria have been removed from nearly 35,000 acres of marsh habitat at Blackwater Unit and surrounding private marshes. Nearly 92% of trapping units remain nutria free as long as 15 months post removal, indicating that nutria eradication from Chesapeake Bay marshlands may be possible.

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Louisiana Coast-wide Nutria Control Program: Year Two

Nutria damage along coastal Louisiana was first reported in the late 1980's and was documented during aerial surveys that began in the early 1990's. In January 2002, the Coastal Wetlands Planning Protection and Restoration Act task force approved the Coast-wide Nutria Control Program, a program that provides a $4.00 per nutria tail incentive payment to participants. The program objective was to remove 400,000 nutria from the Louisiana coast and was implemented by the Department of Wildlife and Fisheries. The boundaries of the program area were established and an application process was developed. Applicants were required to have a valid Louisiana trapping license and landowner permission of the property to be trapped / hunted. A map with property boundaries and a legal description of the property, including the township, range and section, was submitted so that harvest distribution information could be obtained. Approved applicants received a registration packet containing all pertinent information by beginning of the trapping season. The open trapping season began in mid November and collections began in late November. Participants brought nutria tails (7 inches or greater) to collection sites spread across coastal Louisiana. Participants also indicated the location of harvest on maps of their property which was used for harvest distribution. The trapping season closed at the end of March and the collections ended the first week of April. A final summary with harvest distribution data was prepared.

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Towards a Risk Assessment of Second Generation Rodenticides: Do We have Enough Information to Proceed?

It is undeniable that the use of second generation anticoagulant rodenticides (SGARs) has resulted in notable conservation successes in various parts of the world where rats threaten the viability of sensitive ecosystems. The recovery of islands following the removal of introduced rodents is so evident that the benefits clearly outweigh the impacts related to the poisoning campaign. However, the fact remains that SGARs are among the most problematical pesticides registered today. The number of rodenticide poisoning incidents has steadily increased over the years to the point that they are now as or more frequent than reported insecticide poisonings despite a much smaller volume of use. In New York State, between 7.2% and 10.6% of all bird of prey mortality reported to the authorities between 1998 and 2001 was the result of anticoagulants, almost exclusively SGARs. For great horned owls, it was as high as 17% (Stone et al. 2003 Bull. Env. Contam. Toxicol.70:34). Mortalities of squirrel, chipmunk, raccoon, opossum, fox, skunk and deer have also been uncovered. In California between 1994 and 2003, SGARs were thought highly likely to have caused the death of 5/8 barn owls examined, 3/6 great-horned owls and 4/14 golden eagles. There also the list of affected mammals is extensive: coyote, fox squirrel, kangaroo rat, raccoon, red fox, mountain lion as well as the endangered San Joaquin kit fox (updated from Hosea 2000 19th Vert. Pest. Conf.: 236).

There is a tendency today to think that a paper risk assessment will provide all the answers we need to effectively understand and manage the risk from products such as these. This thinking has become even more entrenched following the advent of probabilistic methods. These methods provide a veneer of credibility to assessments that often remain very shaky at their core. Probabilistic methods typically provide bounds around the parameters of a model. They do not reveal the uncertainties about the fundamental model structure.

The following questions are essential to the conduct of a credible assessment, whether deterministic or probabilistic. Given the extent of model uncertainties, we do not think it likely that a simplistic risk assessment can provide any meaningful answers at this point.

Do we know enough about the sensitivity of non-target species to SGARs?

Anticoagulant rodenticides are very poor subjects for the usual toxicity determination that underpins all risk assessments. For example, of 31 pesticides with repeat exact LD_{50} determinations within the same species, brodifacoum fared the second worst in terms of inter-test variation with 15-fold difference between calculated LD_{50}s. Lethality from anticoagulant rodenticides is highly dependent on the length of the post-dosing observation period as well as on husbandry issues. Small nicks, cuts or bumps which are part of daily life for a caged bird become life threatening with these compounds. Furthermore, rodenticides are probably the only pesticides that have been tested with a concurrent administration of the antidote at unspecified levels. The pharmacological literature is rife with reports of phylloquinone (vitamin K1) interfering with anticoagulant therapy. Yet, toxicity tests are conducted on animals given a base feed that may be rich in vit. K1 (present at high levels in soy and alafalfa for example) and which is further supplemented with menadione (synthetic vit. K3). There is some indication that at least part of the wide variation in reported brodifacoum toxicity to the mallard may be the result of differential vit. K supplementation. Applying the usual species sensitivity distribution techniques to the existing toxicity database may not be very meaningful if all of the toxicity data points are suspect. Similarly, it is difficult to place too much belief on comparative assessments that are based on toxicity data.

Furthermore, because of the widespread contamination now being reported, the base risk scenario today is not likely to be that of a toxicologically 'naïve' individual being exposed to a residue-carrying mouse or rat. For example, based on the long term UK based Predatory Bird Monitoring Scheme (updated from Burn et al. 2002 Aspects Appl. Biol.: 2003), the proportion of barn owls already carrying residues is approaching 50% and the summed liver residues now average approximately 0.1 ppm. A sample of aymptomatic birds of prey from NY State (Stone et al. 2003 op.cit.) indicate that 77% of great horned owls, 50% of red-tailed hawks, 43% of screech owls and 35% of Cooper's hawks have been exposed. Recent data from central Canada (Ontario and Manitoba samples) obtained with a sensitive triple quadrupole LCMS-MS instrument indicate that it is becoming difficult to find uncontaminated great horned owls in populated areas and that the majority of birds now carry multiple rodenticide residues, primarily SGARs. Whereas the toxicological significance of these residues is not known, we can surmise a general increase of susceptibility to anticoagulation as a result of this extensive pre-exposure in wildlife populations.

Do we know how non-target species such as birds of prey are exposed?

The dominant routes of exposure are thought to be clear in the case of birds of prey that are acknowledged to take commensal rodents on a frequent basis – for example barn owls worldwide, red kites in the UK. However, patterns of exposure both in the UK and in North America suggest much broader contamination of the terrestrial environment. For example, the high frequency of exposure in Cooper's hawks from New York State (35%) was unexpected based on the absence of commensal rodents from the known food habits of the species (Rosenfield and Bielefeldt 1993 Birds of N. America). The relatively small proportion of poisoning cases despite the high frequency of occurrence suggests that this species may not be getting exposed through ingestion of poisoned rodents but, rather, through an invertebrate-bird food web. Such a transfer of residues through invertebrates to insectivores has been shown to occur including during whole island rat control programs (e.g. Howald 1997 U-B.C., M.S. Thesis). The extent of insectivore food chain contamination in agricultural and sub-urban landscapes has yet to be confirmed.

Examples of exposure to multiple rodenticides abound from the U.S., UK and Canada. This may be a result of very frequent exposure to poisoned rodents or again denote a very widespread contamination of the environment at large. A complicating factor has been the discovery of cross contamination of rodenticide products at trace levels. Our latest data from Ontario suggest multiple exposure rather than widespread cross-contamination of bait material. In any case, based on the great horned owl data mentioned earlier, it is prudent to assume that all members of a population of raptorial species will be exposed to contaminated prey regardless of what the literature says about their preferred food habits.

Information from the UK appears to suggest that restricting anticoagulants to indoor use results in a lower level of environmental contamination as witnessed by the smaller preponderance of brodifacoum and flocoumafen (indoor use only – only 1-6% of barn owls carry residues) relative to that of difenacoum and bromadiolone (indoor and outdoor use – 20-30% of barn owls carry residues). However, the difference is readily explained by sales volume alone. If one looks at brodifacoum residues, for instance, the frequency of detection in barn owls is approximately 4 times the frequency of difenacoum or bromadiolone detection based on the number of farms using the product. The more restrictive labeling, therefore, does not result in a lower frequency of detection in the barn owl at least. Unfortunately, good use data is lacking for the North American market.

Do we understand the consequences of sublethal exposure?
The vast majority of aymptomatic birds in which we find low levels of rodenticides have obviously survived acute intoxication. This does not mean that there are no other possible consequences of this contamination. This is an aspect that has been mentioned by several researchers. Concerns remain because of possible hepatotoxicity as well as disruptions of osteocalcin-dependant processes whether loss of calcium leading to osteoporosis or calcium remobilization and deposition in the circulatory system. The increased sensitivity of these birds following a re-exposure has already been noted earlier.

A particularly worrisome research finding has been the report of brodifacoum toxicosis in neo-natal dogs following a past sub-lethal exposure in the female (Munday and Thompson 2003 Vet. Pathol. 40:216). The risk of trans-placental transfer is of obvious concern given the high proportion of mammals found carrying residues including endangered species such as the kit fox.

In short, we find ourselves in the same situation now than in the early days of the discovery of widespread contamination of non-target species by organochlorine insecticides. We can see the extent of the contamination but cannot yet understand all of its ramifications. It is doubtful that answers to these questions will come from a risk assessment process developed to deal with typical pesticides of short environmental persistence. Until we fully understand the consequences of environmental contamination from SGARs, it behooves us to weigh very carefully the benefits of their use.

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Rodent Declines and Invasions in the Florida Keys

The critically endangered Key Largo woodrat has undergone a serious decline in recent years. A population viability analysis was conducted in 2003, predicting extinction of the species within 10 years. Trapping conducted during 2003-2004 continues to indicate a declining population. A captive breeding program was initiated at Lowry Park Zoo and the first young were produced on May 10, 2003. To date, 13 wild-caught woodrats have been brought into captivity (9 males and 4 females) and 14 young have been produced.

Assumed threats for the Key Largo woodrat population in the wild include secondary impacts as a result of development including black rats, cats (feral and domestic), raccoons, and fire ants. The effects of these threats on the Key Largo woodrat population are difficult to evaluate because few data are available on the abundance of these species. The magnitude of threat from each of these species on the woodrat is difficult or impossible to determine without further study. All of these species are widely-accepted threats to small mammal populations, though we do not have direct evidence of their impacts on the Key Largo woodrat. Some of these impacts have been temporarily addressed. Any incidental black rats captured during woodrat trapping efforts were removed and necropsied to determine if any diseases are present in the black rat population that may potentially affect the Key Largo woodrat population. During 2003-2004, USDA/APHIS Wildlife Services was contracted to remove feral cats from north Key Largo. Fire ants are being treated on the right-of-way on County Road 905. No noticeable rebound has been observed to date in the Key Largo woodrat population as a result of these actions.

Anecdotal information on a new invasive species has recently been reported in Key Largo. The Gambian pouch rat has now been documented to occur on Grassy Key and unconfirmed sightings of Gambian pouch rats have been reported in Key Largo. Although no control or eradication measures are currently underway, some trapping is being conducted by a graduate student from Texas A & M University. Captured individuals are being tested for possible zoonotic diseases.

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An Overview of Rodent Contraceptive Development at the USDA/APHIS Wildlife Services, National Wildlife Research Center

Rodent control has traditionally be accomplished by lethal methods. Contraceptive methods are currently experimental, but the potential for effective control using contraceptive agents is promising. Because different contraceptive methods may be advantageous in different situations, development of a variety effective fertility control measures may be valuable. Contraceptives in general have some advantages over poisoning that will be useful in some rodent control situations. Bait shyness should not occur with contraceptives because the result occurs later than ingestion. In most cases, contraceptives are safer to humans and non-targets than lethal control chemicals. Non-lethal control is generally more accepted than lethal control. And some contraceptives may actually provide better population reduction than lethal control.

A collaborative effort with government agencies in California demonstrated that contraceptive methods can be used in rodents. The overabundant California ground squirrels were in a park where lethal control was not an option. An injectable GnRH vaccine was used in the ground squirrels. The effort was successful as measured by several parameters, but the trapping required to be able to inject the vaccine was time consuming.

Because injection is not practical in most situations, development of oral contraception methods would be a great advantage. Both chemical compounds and oral contraceptive vaccines are under development at NWRC. The potential for chemical inhibition of fertility has been demonstrated in preliminary studies. Further investigation is ongoing. Developing effective oral vaccines is difficult, but NWRC scientists are working on several possible formulations that may make effective oral immunization possible.

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Assessing Potential of Applying Baits on Native Marshes to Reduce Nutria Impacts

Nutria (*Myocastor coypus*) were first introduced to the United States for their fur, and some populations remain economically important to the fur industry. Accidental and intentional releases have permitted them to establish in wetlands across the United States. Burrowing and foraging by nutria can be devastating to native vegetation. Nutrias are recognized as factor in a decline of native marsh along the Louisiana coastal and on the Chesapeake Bay. Placing zinc phosphide treated baits on rafts in canals or ponds has effectively reduced nutria numbers on croplands. However, a similar effort on native marshes may not work as well. Bait acceptance may be low because nutria may elect to ingest alternative native foods and non-target impacts may be different. We conducted a series of experiments in cooperation with the Louisiana Department of Fish and Wildlife to assess potential of applying baits on native marshes. An initial study revealed low bait acceptance during late spring, possibly because an abundance of marsh plants. This study was repeated during the following winter when native plants were less abundant. Nutria activity on rafts remained low, foraging activity markers indicated that only 4% of the population had consumed bait treated with metallic flakes and tetracycline. Related studies assessed the use of olfactory, visual and audio attractants to encourage nutria use of rafts. Although a strong attractant was not obvious among tested stimuli, nutria appeared responsive to olfactory cues. Visual and audio cues were not well attended.

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Invasive Species Research at the USDA National Wildlife Research Center, Hilo Field Station

Introduced rodents have historically caused a myriad of health, economic, and environmental problems in Hawaii and the Pacific Basin. The roof rat (*Rattus rattus*), Norway rat (*R. norvegicus*), Polynesian rat (*R. exulans*), and house mouse (*Mus musculus*) are found in many diverse habitats throughout the major Hawaiian islands. Since 1967, the NWRC Hawaii Field Station, located on the island of Hawaii, has been actively conducting research to reduce the impacts of these invasive vertebrates in agricultural crops and on rare and endangered native floral and faunal resources throughout the Pacific Basin. The agricultural emphasis has historically focused on sugar cane and macadamia nuts, but more recently has shifted to tropical fruits, ornamental foliage and flowers, seed corn, vegetables, and other crops. The Hawaiian Islands are known to have the greatest number of endangered plant and animal species in the world. Rare native plants, snails, invertebrates, and birds are severely threatened by disease, loss of habitat and predation. Rats rank high as predators that are responsible for suppressing seed regeneration of endemic plants, reducing populations of native snails, and significantly limiting the breeding success of many native avian species. Field Station staff have been actively working to develop rodenticides to use in conservation areas to either reduce rat effects or to eliminate them when possible. **[POSTER]**

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Accidental Discharge of Brodifacoum Baits in a Tidal Marine Environment: A New Zealand Case Study

Brodifacoum is a second-generation anticoagulant used worldwide in bait formulations for commensal rodent control, and in some countries for field control of vertebrate pests. As the result of a New Zealand road transport accident in May 2001, a tidal marine environment was exposed to up to 18 tonnes of rodent bait (c. 360 g of brodifacoum) as a point source, which was an unprecedented incident. Immediate monitoring of marine biota, water and sediment was undertaken. This was particularly important because the area was used for human food collection. No local mortalities of marine birds or mammals were attributed to the spill. Contamination of the marine environment was localized in about a 100-m^2 area. The decline of brodifacoum residues in algal-grazing and filter-feeding marine invertebrates over a three-year period is described. A ban by New Zealand authorities on the collection of shellfish from the area was lifted in May 2004. The decline of brodifacoum residues in various sample media was probably due to a combination of physical dispersal (rather than chemical degradation) of brodifacoum in the highly dynamic tidal marine environment, and a previously undescribed and relatively long retention (half-life) of brodifacoum in marine molluscs.

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Managing Roof Rats (*Rattus rattus*) to Reduce Their Impacts on Open-cup Nesting Songbirds in Riparian Forests of the Central Valley, California

In 2001, we identified roof rats (*Rattus rattus*) as potential predators of songbird nests in old growth riparian forests of California's Central Valley. With nest predation rates for some open-cup nesting species as high as 80% in some years, and extremely high trap success of roof rats in songbird nesting areas, it was clear that a cost-effective management strategy to reduce rat impacts on songbirds was necessary. Following a review of the literature and consultation with land managers and experts in rodent management and bird conservation, we developed a baiting strategy aimed at reducing rat populations immediately prior to the songbird nesting period. We conducted studies to provide information on rat home range and habitat use, the most effective bait, optimal bait station placement and distribution, and the potential non-target hazards of the program. We implemented the baiting strategy in one riparian forest tract in October – December 2003, with maintenance baiting during the spring songbird nesting period. Preliminary results indicate that the strategy was effective in reducing rat populations and their predation on nesting songbirds. Although material costs were relatively low, the labor involved in placing and monitoring bait stations, and the inaccessibility of densely vegetated sections of riparian forests may be impediments to implementing this strategy on a larger scale.

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Chlorophacinone Baiting for Belding's Ground Squirrel

In May 1996, efficacy investigations were conducted by the USDA National Wildlife Research Center (NWRC) near Dorris, CA using 0.01% chlorophacinone (CAS No. 3691-35-8) on steam-rolled oat (SRO) groat baits (EPA SLN CA-890024) as a rodenticide. Chlorophacinone was applied by spot-baiting/hand baiting methods using 0.01% SRO baits (i.e. bait scattered around burrow entrances). Spot-baiting was used to control free-ranging Belding's ground squirrels (*Spermophilus beldingi*) in alfalfa (Medicago sativa). Study design included six square treatment units (TUs), 4 treated with chlorophacinone and 2 were treated with a placebo (SRO groat baits without the chlorophacinone). Each TU was 0.4 ha (1.0 acre) and to reduce post-treatment ground squirrel immigration on to the TU a square 5.5 ha (13.8 ac) buffer zone was established around each TU and was similarly treated. A minimum of 50 m (164 ft.) separated all buffer zones. The baits were formulated by a commercial supplier; quality control assays indicated the mean percent of chlorophacinone (w/w) was 0.0109% (SD± 0.00008%) for the nominal 0.01% bait. Bait (11.5 g) was applied according to label specifications by trained applicators on May 13, 1996. Baits were reapplied on May 20 and May 22 for spot-baiting, because of 9 days of unforecast wet weather that greatly decreased ground squirrel activity and made the spot baits swell by absorbing water. As a result, the baits were not preferred forage for the ground squirrels. On May 20, following increased ground squirrel activity with warmer and drier weather, fresh bait was scattered around each active burrow entrance and a second spot-baiting was done on May 22. Following baiting, TUs were searched daily and all intact Belding's ground squirrel carcasses were frozen and kept for tissue analysis. Efficacy of spot-baiting (uncorrected and corrected % reductions), as measured directly by visual counts (73.5% and 64%) and indirectly by open-hole index (80% and 68%), was near the EPA's 70% recommended minimum efficacy standard for rodenticides. Thirty-eight carcasses were analyzed from the spot-baiting TUs by the Analytical Chemistry Project (ACP) at NWRC for chlorophacinone. Of these, 29 (80%) had detectable levels of

chlorophacinone in the liver averaging 0.1279 ppm (SD $\pm$ 0.1314 ppm) and in the whole body averaging 0.1131 ppm (SD $\pm$ 0.0928 ppm). Non-target mortality was not observed in this study. In conclusion, spot-baiting was an effective method to control Belding's ground squirrels, and it could be improved with use: (1) earlier in spring when less alternative forage was available, (2) before the emergence of the young-of-the-year, (3) during drier weather conditions associated with increased ground squirrel activity, and (4) of a third baiting following about 2 days after the second baiting. **[POSTER]**

Mark J. Rauzon, Marine Endeavours, 4701 Edgewood Avenue, Oakland, CA 94602 USA

Elevated Bait Station Trials (and Tribulations) in Crab Country

In an effort to develop the most efficient rat bait station that limits hermit crab depredations, many methods were researched, then tested on Wake Atoll, Pacific Ocean. Local designs from Wake were already being tried to control rats in the post cat eradication predator release. PVC tube and metal stations were screwed into trees in order to limit bait take by land crabs. These models appeared ineffective. Stand-alone Phil-Proof™ and Rat-Go™ models were also tested. The stand-alone Rat-Go™ model was tried extensively in Jul-Aug. 2004. It was initially found to allow crabs to climb up the front and rear supports. As a means to deter climbing, the front edges were wrapped in mylar to prevent crabs from gaining an edge to hold. Rats were initially not recorded entering because the crabs got there first, but the mylar bib showed promise and also recorded rat tracks on its smooth surface when wet with dew. Finally, the supports were indented about one and a half inches. This modification allowed crabs to climb up, but prevented them from gaining entry due to the distance to the edge. Crabs shimmied up and hit the underside of the station and slid back down. Several nights of trials in heavy crab use areas showed the design to be effective in limiting crab depredations while allowing rat access. Modifications were made and Rat-Go™ Elevated Bait Stations were manufactured and are ready for more field trials. **[POSTER]**

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Registration Costs of New Products and New Uses: The Price of Innovations and Solutions

Registration work makes up a significant part of the cost to develop new pesticide products and new uses for existing pesticides, including rodenticides. For a product based on a new active ingredient the research and development phase (R&D) can take 3-7 or more years to generate up to 70 data endpoints to qualify a new material for U.S. Environmental Protection Agency (EPA) registration. All research must be done according to the Good Laboratory Practices (GLP). Conducting all the trials possibly needed to register a new conventional chemical pesticide can cost 50 million dollars in research investment. Clearly, rodenticides can not justify such expense, but the R&D bill for a truly "new" product could easily exceed 2 million dollars. New uses for existing products carry less development expense, but costs remain an important consideration. Figures for R&D do not include registration fees. EPA's review of registration dossiers is now subject to the Pesticide Registration Improvement Act (PRIA) of 2003, with 90 different categories for pesticide registration service fees. The PRIA is intended to create a more predictable evaluation process for affected pesticide decisions, and couples the collection of fees with specific decision review periods. The legislation also promotes shorter review periods for reduced-risk applications. Fee waivers and reduced fees are available in certain situations, such as IR-4/minor uses, federal and state agency exemptions, and small business registrants. The fee for EPA's Registration Division to review a New Rodenticide Active Ingredient for "Non-food use, outdoor" applications is $330,000 for registrants not eligible for waivers. Depending on when data is submitted, the decision review period would be 21 to 32 months for this category. The Agency's fee to review a New Use for an existing rodenticide for "non-food use, outdoor" applications is $20,000 for waiver-ineligible registrants, and the decision review period would be 15 to 28 months. While invasive rodent problems can be partially solved by the judicious use of rodenticides, new technological developments in this arena will carry a price tag for such innovations and solutions.

J. Jeffrey Root, USDA/APHIS, Wildlife Services, National Wildlife Research Center, 4101 Laporte Avenue, Fort Collins, CO 80521-2154 USA

Hantaviruses in the Western Hemisphere: A Review

Several hantaviruses can be found throughout the Western Hemisphere. Some of these New World hantaviruses are etiologic agents of hantavirus pulmonary syndrome, an often fatal zoonotic disease. Several species of rodents belonging to the family Muridae are the primary hosts of New World hantaviruses. Through years of research, multiple workers have indicated that each hantavirus typically has a single primary rodent host (e.g., the deer mouse, *Peromyscus maniculatus,* is the host of Sin Nombre virus); however, multiple workers have documented antibodies to a hantavirus in rodent species not known to be a primary host of a hantavirus. In this talk, virus/host relationships, transmission cycles, and risks to humans are reviewed for hantaviruses found in the New World.

J. Jeffrey Root, Jeffrey S. Hall, Robert McLean, and Larry Clark, USDA/APHIS, Wildlife Services, National Wildlife Research Center, 4101 Laporte Avenue, Fort Collins, CO 80521-2154 USA; Nicole I. Marlene and Barry J. Beaty, Arthropod-borne and Infectious Diseases Laboratory, Colorado State University, Fort Collins, CO 80523; Justin Gansowski, USDA/APHIS Wildlife Services, 1930 Route 9, Castleton, NY 12033

Sero-survey for Antibodies to Flaviviruses in Wild Mammals in Central and Eastern United States

Sero-surveys were conducted to detect antibodies to flavivirues and West Nile virus (WNV) in wild mammals. Two different monoclonal antibodies (6B6C-1 and 3.1112G) were used. More than 500 serum samples from over twenty mammal species captured in five states (CO, LA, NY, OH, and PA) were screened. Sera samples containing antibodies to flaviviruses were screened for WNV-specific antibodies and confirmed with plaque reduction neutralization tests. Antibodies to flaviviruses were detected in multiple species. This number was significantly reduced for WNV as was the overall prevalence of antibodies, indicating that multiple flaviviruses may have been present at some study sites. High prevalence rates for WNV antibodies were noted among raccoons, Virginia opossums, fox squirrels ,and eastern gray squirrels. **[POSTER]**

Terrell P. Salmon, University of California Cooperative Extension – San Diego
5555 Overland Avenue, Suite 4101, San Diego, CA 92131 USA

Rodent Control Techniques: Can We Learn from Agricultural Uses?

Rodents are controlled in many different agricultural settings. While the primary reason for these programs is to reduce economic damage, the overall goals are similar to many rodent control efforts for conservation of wildlife or natural resources. Since most agricultural rodent control programs are based, or at least theoretically conceived, on a cost/benefit model, the control is done when it is economic for the producer. In conservation efforts, the same model is used but the control threshold is likely at a different level. While eradication is often the goal in conservation efforts, it is seldom the definition of success in agricultural situations. However, much effort and research on agricultural rodent control is focused on improving efficacy; making the pest control goals for agricultural and conservation much the same. In this presentation, I will review some baits (include their composition), baiting strategies and application equipment that are all used in agriculture to improve the efficacy of the control program while reducing primary and risks to non-target species. An understanding of the judicious use of rodenticides, new technological developments in this arena will carry a price tag for such innovations and solutions.

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Stephanie Shwiff, USDA/APHIS Wildlife Services, National Wildlife Research Center, 4101 LaPorte Ave, Fort Collins, CO 80521-2154 USA

Benefit-Cost Analysis of Rodent Control for Conservation

Noticeably absent from most rodent damage management studies is a benefit-cost analysis (BCA) to provide an accurate estimate of total damages and justification of damage management efforts. BCA of rodent control involves comparing all of the gains and losses from a given rodent damage management action or technique in similar units; thereby providing a picture of the total gains and losses to society. The costs of rodent control include costs for bait, labor and machinery and are usually contingent on the timing of the baiting (e.g. outbreak situations). Direct benefits of rodent control incorporate reduced damage to crops, facilities, electrical systems, feed, etc. Indirect benefits could include reduced spread of disease and intangible benefits can include things like reduced mental stress as a result of rodent plagues. An example highlighting the protection of the endangered Puerto Rican parrot (*Amazona vittata*) from predation by the black rat (*Rattus rattus*) illustrates the importance of BCA in studies examining rodent control for conservation. With increased efforts for island rodent eradication programs to aid in the recruitment of shore birds, the use of BCA is imperative.

Art Sowls and G.V. Byrd, USDI/FWS Alaska Maritime National Wildlife Refuge, 95 Sterling Highway, Suite 1, Homer AK 99603-7473 USA

Preventing Rat Introductions to the Pribilof Islands, Alaska, USA

The Pribilof Islands have about three million nesting seabirds, a million northern fur seals, an endemic shrew, and other wildlife. Rat introduction would greatly reduce bird and shrew populations and might transfer diseases to humans and wildlife. The islands have been inhabited since 1786, and although the lack of harbors impeded rodent introduction, house mice became established on St. Paul in 1872. In the early 1990's, harbors were constructed on both St. George and St. Paul Islands. A boom of commercial fisheries soon followed and eventual rat introduction seemed a certainty. With the objective of keeping the Pribilofs rat free, a prevention program was begun in 1993 based on cooperation with local communities, government agencies, and industry. The program consists of maintaining trap and poison stations, community education, local shipwreck response capabilities, outreach to make ships rat free, and regulations. Over a million trap nights have passed and six rats have been killed on the St. Paul docks, but there is no evidence of rats becoming established anywhere in the Pribilof Islands. Improved design of preventive stations has decreased maintenance needs. Snap traps have been more effective than poisons, but have caused some non-target loss (winter wrens). Both techniques are recommended. The local communities are taking increasing ownership in the program and it appears that fewer ships using the Pribilof Islands carry rats. Unless there is a major advancement in rodent removal technology, the prevention program will have to be continued indefinitely. It is too early to be certain that the program is adequate to protect the Pribilof Islands, but as each rat-free year passes, hopes are rising. Technical advice from Rowley Taylor, Joe Brooks, and Paul O'Neil was instrumental in the initiation of this program. **[POSTER]**

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Preventing Rat Spills on U.S. Alaska Maritime National Wildlife Refuge: A Preliminary Approach

Shipwrecks have caused rodent introductions world wide and continue to be a threat. The first documented rat introduction on Alaska Maritime NWR occurred in 1780 when a Japanese ship went aground on what would later be renamed Rat Island. The Alaska Maritime NWR is responsible for conserving the unique ecosystems and biodiversity of about 3.5 million acres, including the Aleutian Islands International Biosphere Reserve—a special designation in recognition of the uniqueness of the region on a global scale. Prevention of further introductions is of primary concern and should be the cornerstone of any invasive species program. Stopping introductions is both more ecologically effective and cost-efficient. The Refuge established a shipwreck response team in 1995 in an effort to protect over 2,000 islands, rocks and spires spread across 2,500 miles of the Great Circle trade route from rodent introductions. To date, many incidents involving ships in distress have occurred, though actual field responses have been limited to four. Fortunately, none of these ship casualties had rats. Efforts are now underway to improve response capabilities, expand partnerships and enlarge the area for which rat spill response is possible. Questions remain about the most effective ways to stop rat invasions from shipwrecks including appropriate rodenticides and other methods of killing rats, delivery methods, and relevant rat behavior before and after they leave wrecks. **[POSTER]**

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Developing a Rat-IPM Technology for the Philippine Irrigated Rice Lowland Ecosystem

The rat population dynamics were monitored using the trap barrier system÷trap crop (TBS+TC) for four rice cropping seasons in 2002-2004 while their movement to and from the rice field by the linear TBS during the dry season 2004 under the Philippine irrigated lowland conditions. High rat catches were recorded during the period of field operation up to the vegetative stage of the rice plant. At this period, more female rats moved to and from the rice field than the males, but not during the rice reproductive stages. About 12% of the female rats that moved into the rice field at rice vegetative stage were juveniles and the rest had either mated or given birth. At the rice reproductive stages, most have either given birth or lactated before or during the period. The decline in female rat movement at the later stages of rice growth may be related to its nursing activities, protection of the pups, and availability of food nearby. However, additional data is needed to satisfactorily explain these assumptions. Nevertheless, the results indicate that the best time to conduct a community-wide physical rat control system to reduce the initial rat population is at the early stages of the cropping season. Other control measures, like baiting may also be focused at this period and not throughout the cropping period as currently practiced by the farmers to reduce cost and risk. Detailed information on burrow census in and around the rice field, rat sexual status at different rice growth stages, and other related information were to be considered in the continuing study. **[POSTER]**

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The Eradication of Introduced Roof Rats on the U.S. Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands

The U.S. National Park Service and USDA/APHIS Wildlife Services made a planned and sustained effort to eradicate the introduced roof rats (*Rattus rattus*) from Buck Island Reef National Monument in the Caribbean Sea from 1998-2000. The rats were causing substantial damage to a variety of the Island's floral and faunal resources. The WS created an island-wide grid of elevated bait stations and used an anticoagulant (0.005% diphacinone) rodenticide bait block to eradicate the rats. The bait stations were modified several times to assure ready access by rats while minimizing access by non-target animals. Several post-project trapping sessions resulted in no rat captures, suggesting that, indeed, the rats had been eradicated from the Island. No non-target losses resulting from the baiting program were observed by field personnel, but they noted what appears to be a rapid recovery of many of the Island's floral and faunal resources. A post-eradication rodent monitoring protocol has been implemented. Post-project monitoring sessions revealed the presence of a growing house mouse (*Mus musculus*) population on the Island. The threats posed by, and potential management strategies for, this introduced pest species are being investigated.

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Leptospirosis in the Azores: The Rodent Connection

The Azores are Portuguese islands in the North Atlantic Ocean. The culture is very agrarian with a large cattle industry. Unfortunately, there is a chronic leptospirosis problem within the people, livestock, companion animals, and wildlife of the Azores. Introduced rodents (*Rattus rattus, R. norvegicus, Mus musculus*) play a significant role as maintenance hosts of this disease. We review the situation and make recommendations for reducing the occurrence and hazard of leptospirosis in the Azores. Areas addressed include the need for a better understanding of the epidemiology of the disease and the role of rodents, development of an effective rodent control program, improvements in farm practices and animal husbandry, and improvements in the Azores infrastructure to effectively reduce the leptospirosis hazard.

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Are Both Rat Species, *Rattus rattus* and *R. norvegicus*, Omnivorous?

The roof rat (*Rattus rattus*) complex as well as the Norway rat (*R. norvegicus*) are often called omnivores. However, the food habits of the roof rat are different from those of the Norway rat. In this survey, roof rats mainly ate plant materials and the average volume percentage of their stomach contents was usually over 90% with seeds and fruits being more than one-third of those plant materials. The rest of the contents were mainly insects. As for Norway rats, the volume percentage of plant materials in the stomach contents varied by study sites and was between 14-74% on average. The rest of the contents were animal materials such as insects,

annelids, snails, and fish. Therefore, the roof rat chose far more plant materials than animal materials as food, whereas the Norway rat chose both of them in similar volumes.

The roof rats, however, showed unusual food habits when they were thirsty or food was in short supply. Roof rats on a desert island covered with volcanic ash in Japan preferred succulent herbaceous stems (53.2% in volume) to seeds (28.8%) probably to increase water uptake. In another case, roof rats on a remote island of southern Japan ate bark and an excessive amount of insects when starving. Rat stomach contents included 44.1% of animal materials (chiefly insects) and 8.9% of soft tissues of Citrus tankan bark on average in volume. It is supposed that this unusual food habit is caused by food shortage after a population outbreak. In conclusion, it appears that the roof rat complex is basically herbivorous and the Norway rat is basically omnivorous, although the roof rat changes food habits when it is thirsty or food is in short supply.