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Wildlife Damage Management: Changes over the Last 40 Years and a Look at the Future

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Keynote Address

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ABSTRACT: Since becoming a wildlife biologist 40 years ago, I have seen many changes. Yet some things have remained the same, like the economic impact of wildlife damage, which was high in 1974 and even higher now. In 2014, the worldwide cost of damage by vertebrate pests to agriculture will exceed $1 billion. The world's human population has increased at an unprecedented rate, while some wildlife populations have also burgeoned over the past 40 years due to land-use changes and effective management programs. These simultaneous human and wildlife population increases have led to increasing conflicts between humans and wildlife. Nor has the international nature of damage changed: vertebrate pest control remains vital for agricultural production everywhere. And some types of wildlife damage are unchanged, such as livestock predation, bird damage to agricultural crops, and rodent damage to crops and stored grains. What has changed over the last 40 years? I see increasing complexity in the types of problems, in the solutions, and in the political landscape under which we work. Damage problems have become more complex, with invasive species being transported around the world, and with zoonotic diseases associated with wildlife becoming more prevalent. Solutions to damage problems have also become more complex, as simpler solutions have already been employed; solutions being sought now are more scientifically difficult and require collaboration by wildlife biologists with an increasing number of other scientific disciplines, such as toxicologists, geneticists, and epidemiologists. And society itself has become more complex, demanding solutions that not only prevent damage, but that are environmentally sound and politically acceptable. What does the future bring? Human population growth will mean more wildlife damage issues. Greater travel and international shipping will bring an increase in invasive species, and global warming will bring an increase in zoonotic diseases. Solutions will need to be innovative and reflect the complexity of the problems.

KEY WORDS: history, research, techniques, tools, wildlife damage management, Wildlife Services

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Welcome to the Vertebrate Pest Conference. I am honored to be your keynote speaker today. I retired from the USDA Wildlife Service's National Wildlife Research Center [NWRC] in July 2013 and have been asked today to talk about the changes that have occurred in the wildlife damage management field during the 40 years that I worked at the NWRC. I will talk primarily from the perspective of federal research, which is what I am most familiar with. I will talk about some things in the wildlife damage management field that have not changed, what has changed, and my predictions for the future.

I would like to start with a bit of background on federal wildlife damage management. The program dates back to 1885 when the U.S. Congress appropriated $5,000 to fund the Division of Economic Ornithology and Mammalogy, to study the distribution of life in America, with reference to use as agricultural and horticultural products. The Division in 1905 became the Bureau of Biological Survey (BBS) under the USDA and by 1915 shifted its focus by establishing districts in 8 western states to provide solutions to the problem of predatory animals killing valuable livestock. In 1917, the BBS established districts in 8 western states and staffed those districts with field personnel to protect livestock from predatory animals. By 1917 the BBS had established districts throughout the United States and initiated cooperative funding with state and counties; in time, the field personnel worked in both predator and rodent control. This use of local districts and cooperative funding remains the model under which USDA Wildlife Services still functions.

In 1922 the BBS established the Eradication Methods laboratory in Denver, Colorado for "investigation of poisons and their preparation which will aid the effectiveness of campaigns to destroy predators and rodents." In 1931 the Animal Damage Control Act was passed by Congress, which authorized the operational and research activities, cooperative agreements, and exchange of funds, under which Wildlife Services still functions. The Denver laboratory became the Control Methods Research Laboratory and, in 1931, a food habits division was established. At this point the laboratory's mission changed to one of systematic laboratory and field research, with a focus on nonlethal and lethal means of managing damage by mammals and birds (Fagerstone and Keirn 2012). In 1939 the BBS became the Fish and Wildlife Service [USFWS] under the U.S. Department of Interior. When in 1947 the Federal Insecticide, Fungicide and Rodenticide Act [FIFRA] was passed by Congress, requiring federal registration of pesticides, the Denver Laboratory began research toward development and registration of vertebrate pesticides, a role that it still retains. In 1959 the Laboratory name was changed to the Denver Wildlife Research Center [DWRC].

I entered the field of wildlife biology 40 years ago with a Bachelor's degree, working for the DWRC. I have seen many changes during that time, both in the wildlife biology field and culturally. I would like to give a short

cultural background of what the world was like when I started my career. My career was heavily influenced by cultural activities that occurred during the 1960s and early 1970s. In 1962, Rachel Carson published the book *Silent Spring* that documented the detrimental effects of DDT on the environment and on predatory bird populations. This book had tremendous influence and helped launch the environmental movement. In 1964, the Civil Rights Act was passed by Congress, which changed hiring practices and expanded opportunities for minorities and women. In 1966 the Animal Welfare Act was passed: it regulated the handling of dogs, cats, primates, and other animals used in research, and was an example of a growing public concern for animal welfare. In 1969, Neil Armstrong walked on the moon as a result of an increased emphasis on scientific research. All of these events had enormous impact on society and on the role of federal government agencies in conducting research.

The decade of the 1970s was an important time for environmental issues. In 1970, the first Earth Day was observed, the National Environmental Policy Act [NEPA] and the Clean Air Act were passed by Congress, and the Environmental Protection Agency [EPA] was created. In 1972, the Clean Water Act was implemented. Also in 1972, President Richard Nixon issued an executive order banning use of certain poisons (including Compound 1080 and sodium cyanide) on public lands. And in 1973, the Endangered Species Act was passed. These actions changed how wildlife damage management was conducted, by requiring wildlife managers to place more consideration on the effects of management actions on other wildlife and the environment. And these laws put increased emphasis on the need to develop additional pesticides and products for managing wildlife and for conserving endangered species.

At the same time that the U.S. was creating new environmental laws and emphasizing environmental issues, the U.S. economy was thrown into an economic recession and experienced an energy crisis. Early in the 1970s OPEC proclaimed an oil embargo in response to U.S. support to supply weapons to Israel during the Yom Kippur war. What followed was massive fuel shortages and panic. Some gas stations served regular customers by appointment only or closed altogether; businesses and towns shut off electricity to save energy, some towns banned Christmas lights, and a mandatory 55 mph speed limit was set for national highways. At this same time, the Vietnam War was becoming increasingly unpopular and was "ended" in 1973. President Richard Nixon was forced to resign in 1974. That is a brief synopsis of what the world was like when I started my research career 40 years ago.

Since that time, there have been many changes, yet some things have remained constant. What has not changed? One thing that has not changed is the scope of the damage caused by wildlife. Wildlife damage had huge economic impacts in 1974 and still does so in 2014, with the worldwide cost of damage by vertebrate pests to agriculture exceeding $1 billion a year. And the damage caused by wildlife is growing, not declining. The world's human population is increasing at an unprecedented rate. At the same time, dramatic increases in some wildlife populations, such as Canada geese (*Branta canadensis*) and white-tailed deer (*Odocoileus virginianus*), have occurred over the past 40 years due to land-use changes and effective management programs. These simultaneous human and wildlife population increases have led to increased conflicts between humans and wildlife. Also, the international scope of damage has not changed: vertebrate pest control remains vital for agricultural success throughout the world. And the types of wildlife damage are similar: livestock predation, bird damage to agricultural crops, and rodent damage to crops and stored grains are prevalent. Wildlife damage management remains an important endeavor needing solutions.

One other thing that has not changed is the federal budget for wildlife damage research. When I began creating this talk, I expected to be able to report that budgets had increased in the last 40 years for wildlife management research, but I was surprised to find that, when inflation is taken into consideration, budgets have not increased. When thinking about it, I realized that in 1974 the economic downturn meant that federal budgets had been stagnant or declining for a few years; does that sound familiar in 2014? A second economic downturn began in 1979 and lasted into the 1980s that kept federal budgets low. In December, 1985, the Animal Damage Control [ADC] program moved from the U.S. Department of the Interior USFWS to the USDA Animal and Plant Health Inspection Service [APHIS]. The portion of the DWRC that was conducting research on wildlife damage management issues was transferred along with the ADC Program. In the 1990s, the budgets for the ADC program and the DWRC increased considerably under USDA but have leveled off in the last decade in the face of another economic recession and declining federal budgets. Despite the gain in budget amounts, when adjusted for inflation, the federal wildlife damage management budget in 2014 is almost identical to that of 1974 (Table 1).

Table 1. Research funding for wildlife damage management (WDM) in 1974 (Smith 1974) and 2012 (National Wildlife Research Center – budget figure does not include overhead or administration). FY 2012 budget figures are also shown as adjusted for inflation to 1974 dollars.

	FY1974	FY 2012 (in 1974 dollars)	FY 2012
Predators	$1,100,000	$282,270	$1,337,774
Birds	1,000,000	609,746	2,889,791
Mammals	600,000	183,270	868,577
Other	–	324,042	1,535,746
Total WDM Budget	**$2,700,000**	**$2,699,155**	**$12,792,263**

What has changed over the last 40 years? What strikes me most between 1974 and 2014 is increasing complexity in the types of problems, in the solutions, and in the political landscape under which we work. Damage problems have become more complex, with increasing numbers of invasive species being transported around the world and finding new niches to occupy, and with

zoonotic diseases associated with wildlife becoming more prevalent each year. Solutions have also become more complex, as the simpler solutions to damage problems (traps, early toxicants) have been employed with some success, but have not proven adequate to address the problems. Additional solutions are needed. The solutions being sought now are more complex scientifically and require collaboration by wildlife biologists with an ever-increasing number of other scientific disciplines. And society itself has become more complex, demanding solutions that not only prevent damage, but that are environmentally sound, sometimes coupled with conservation objectives, and often expected to be nonlethal. The political landscape demands more in the way of greater accountability to the public. I will focus on each of these areas in more detail.

One major change that has occurred over the past 4 decades involves who is managing the damage and where that management is occurring. The Federal government was actively involved in wildlife damage management in 1974 through the ADC Program and is still actively involved, now as Wildlife Services [WS], the successor to the ADC program) However, the regions of the U.S. served by federal agency personnel have shifted. In 1974, the majority of ADC personnel and resources were located primarily in the west and management involved almost exclusively predator control (mostly coyote control operations). The eastern program was very small. Since then, the eastern program has been greatly expanded. Also, in 2014, federal wildlife management programs are more diversified, including human health and safety, property protection, and wildlife disease management. State agency involvement in wildlife damage management has also changed, but is variable among states, with some states opting to contract with federal agencies for management and some states handling their own wildlife damage issues. Private involvement in wildlife damage management is greater now in urban areas than in 1974 because of the growth of nuisance wildlife control businesses, such as Critter Control.

Another change that has occurred involves which institutions are conducting the research on wildlife damage management. In 1974, university researchers were prominent in conducting this research, particularly at universities such as Bowling Green University and the University of California. In 1974, the majority of the talks given at the Vertebrate Pest Conference were given by state and university personnel. Now the conference is dominated heavily by federal agency personnel, particularly WS, as state and university budgets have declined and wildlife damage programs have shrunk or been discontinued. University programs have changed emphasis over the past 40 years, from a heavy focus on management (primarily game management but also damage management) to a heavy focus on conservation biology.

At the NWRC, I have seen numerous changes in the types of personnel conducting the research. The scientific disciplines of research staff have changed over the last 40 years as a result of the increase in complexity of the wildlife damage issues. In 1974, 74% of the professional personnel were classified as wildlife biologists (37 of 50 professional positions) compared to 46% (26 of 57 positions) classified as wildlife biologists in 2014. Chemists, pharmacologists/toxicologists, physiologists, and statisticians have remained as core scientific disciplines but new disciplines have been added to the NWRC roster, including economists, registration specialists, geneticists, epidemiologist/disease biologists, population modelers, and a technology transfer manager. The number of women in wildlife damage management has also greatly increased because of changes in U.S. cultural values. In the 1970s there were very few women in wildlife biology university programs and I was the first woman biologist at the DWRC. Today, women make up half or more of most university wildlife biology departments. At the NWRC there are now 13 women in professional series positions; 27% of the professional job grades and one-third of the research grade positions are filled by women.

Areas of research emphasis at the DWRC/NWRC have shifted through the years. Funding for research areas in 1974 was broken down into 3 categories, with predator research (livestock predation in the west) receiving $1.1 million, bird research $1.0 million, and small mammal research $0.6 million (Smith 1974). The predator damage research areas included damage assessment (32% of the $1.1 million predator budget), development of methods (32%), population ecology (23%), and behavior studies (9%). Because of the ban on use of predacides on public lands, NWRC researchers were essentially barred from conducting toxicant research in the field for predators, so there was more emphasis on ecology and behavior research for predator research than for those research areas on birds and mammals. The research areas of emphasis have remained similar for predators through the years. The exception is that the areas of focus have changed from coyote predation in the west to a focus on coyotes in eastern states and on other predators as well.

Some of the research priorities for bird damage management have changed since 1974 and some have remained. In 1974 the top commodities listed as research priorities, in priority order, were sprouting corn, sunflowers, sweet corn, fruit, small grains (primarily sorghum), rice, bird roosts, and feedlots. The priority research methods included repellents, toxicants, frightening devices, and reproductive inhibitors. The priority species of concern were blackbirds and starlings because of their damage to corn, sunflowers, rice, roosts, and feedlots. In 1974 the primary small mammal research priority was damage to forest products, including damage to seeds, clipping of seedlings, and girdling of large trees. Forestry damage from pocket gophers (*Thomomys spp.*) and deer (*Odocoileus* spp.) was considered to be a large problem during the 1970s and the DWRC received considerable funding from private industry for research. Next in importance was damage to the commodities of crops and grasslands by prairie dogs (*Cynomys ludovicianus*) and ground squirrels (*Spermophilus* spp.), followed by sugarcane damage by rats (*Rattus* spp.), damage to vegetables and orchards [primarily by voles (*Microtus* spp.)], and to industrial stored products by rats. Regarding methods

development, most of the research effort was directed to development of repellents and rodenticides, followed by mechanical devices and habitat manipulation.

My personal research in the late 1970s and early 1980s followed the above general research priorities. I began my career conducting research on potential new rodenticides and also worked on studies to assess the nontarget risks of currently registered pesticides such as Compound 1080, strychnine, and zinc phosphide. The main research focus for me in the mid-1970s was the study of grassland rodents, with the project objectives being to develop information on the rodents that would help with development of management techniques for minimizing damage to rangeland and crops. One research project focused on prairie dogs, including studies on food habits (for my Master's degree), competition with cattle, and colony expansion. In the late 1970s my research project was a study of the ecology and behavior of Richardson's and Wyoming ground squirrels, and I obtained my Ph.D. working on these rodents.

After the passage of the Endangered Species Act in 1973, the USFWS began to put more of its resources into conservation management, and the DWRC was increasingly conducted research on newly listed endangered species. My personal research also followed in that trend. A colony of black-footed ferrets was discovered in Wyoming in 1981 and I became part of team studying their home range and movements beginning in 1983. All of the wild ferrets were taken into captivity in late 1985, after an outbreak of canine distemper reduced their numbers to dangerously low levels. At the same time, the ADC program was transferred from the USDI USFWS to the USDA APHIS. The personnel at the DWRC who were conducting research on wildlife damage management were transferred along with the ADC program and, with my black-footed ferret research ending, I also transferred to USDA.

One Congressional action in 1988 has had a major effect on the profession of wildlife damage management, on Wildlife Services, on the DWRC/NWRC, and particularly on my career. In 1988, Congress passed amendments to the Federal Insecticide, Fungicide and Rodenticide Act [FIFRA88]. These new amendments mandated that all previously registered pesticides be reregistered with the EPA and required new studies to determine product chemistry, human and animal health risks, efficacy, and environmental fate for each pesticide (Fagerstone 1990, Ramey et al. 1992). I was selected to lead the reregistration data development process for APHIS/WS pesticide products, and I spent the remainder of my career at the DWRC/NWRC as a supervisor and manager of research projects and programs. Between 1989 and 1998, beginning with a staff of 12 people and with a registration manager (Ed Schafer), we accomplished the reregistration of pesticides critical to the mission of WS. Originally the EPA requested 400 studies that would have taken a total of $14 million to complete (Table 2). My team was able to achieve a reduction in the number of studies required by developing effective communication with the EPA and demonstrating that many of the studies were inappropriate, or the data were already available. Eventually DWRC submitted 250 studies at a cost of only $3 million (Table 2). The communication bridge with the EPA that was built during that period continues today for APHIS/WS. Also at this time, I developed and led a consortia of registrants for some minor use pesticides that allowed for funds to be raised to conduct EPA-required studies. Without the efforts of the DWRC, a number of pesticide products important to the wildlife damage management community (including the field rodenticides strychnine and zinc phosphide, the avicide DRC-1339, the M-44, the livestock protection collar, and the gas cartridge) would not be available for use today.

Table 2. Number and cost of GLP studies required for reregistration of WS pesticides under FIFRA88 and the number actually submitted by WS after negotiations with the EPA to remove unnecessary studies.

APHIS Active Ingredients	EPA Required		Submitted	
	Number	Cost ($)	Number	Cost ($)
Compound 1080 (LPC)	55	1.5 million	40	700,000
Sodium Cyanide (M-44)	56	1.3 million	29	100,000
DRC-1339	68	2.1 million	44	500,000
Strychnine	69	2.5 million	34	725,000
Zinc Phosphide	75	4.2 million	56	750,000
Gas Cartridge (sodium nitrate & carbon)	110	2 million	24	290,000

Table 3. Number of end use pesticide products and active ingredients registered as bird control agents between 1978 and 2012.

	1978	1988	1998	2012
End-Use Product Labels				
Lethal	35	32	12	11
Nonlethal	32	33	18	16
Active Ingredients				
Lethal	5	5	3	2
Nonlethal	10	10	5	4

FIFRA88 had a large effect on the wildlife damage management field in general, not just on Wildlife Services. A large number of products were removed from the market, some because they were hazardous to other species (strychnine aboveground uses are an example; Fagerstone and Hegdal 1998), and others because the data requirements were too costly and the studies were not completed (Compound 1080 as a rodenticide) (Fagerstone et al. 1990, Ramey et al. 1992). Bird control products (both lethal and nonlethal) serve as an example of the loss of pesticide products after the passage of the 1988 FIFRA amendments (Table 3). The number of active ingredients (the concentrated chemicals used to formulate the products actually used) registered for bird management declined from 15 in 1978 and 1988 to 8 after the reregistration process, and is now down to only 6; some of these were repellents that were either determined to have toxic effects or for which data requirements were too costly to justify their continued use. Toxicants have always played an important role in

managing certain overabundant species, including English sparrows (*Passer domesticus*) and European starlings, both of which are nonnative to the U.S and cause tremendous crop damage. Three of the 5 active ingredients available for use by managers as toxicants in 1978 were cancelled after 1988. Strychnine as an active ingredient for aboveground bird and rodent uses was cancelled primarily because of potential nontarget hazards. Fenthion, an active ingredient used to kill roosting nuisance birds in structures, was also discontinued. And the wetting agent PA-14 was not registered, because WS determined that the high cost of required studies could not justify the limited use of the product for reducing large blackbird roosts. Between 1998 and 2012, two nonlethal techniques (naphthalene and polyisobutylene chemical repellents) were also discontinued. Many end-use products (the formulated products labeled for use) that contained the cancelled active ingredients were also discontinued after the increasingly stringent reregistration data requirements (Table 3). The number of end-use products declined from 65 in 1988 to only 27 in 2012. This loss of products in the 1990s led to a need for research to develop new management techniques.

Research was begun in the 1990s toward development of alternative products that can be used to manage bird problems. As part of this effort, the bird contraceptive nicarbazin was developed and registered with the EPA as a partnership between the NWRC and private industry (Fagerstone et al. 2008). To address the need for new products and to determine what areas of research should be a priority, in 1990 the NWRC conducted a research needs assessment and queried wildlife managers both within and outside APHIS regarding their most important damage problems (Packham and Connolly 1992). Managers ranked both the importance of the resource groups damaged and species responsible for the damage. The national ranking of resource groups by ADC state directors was (highest priority first): 1) grain, *2) nuisance*, 3) livestock, 4) structures, 5) *aircraft, 6) fish*, 7) forestry, 8) fruit/berry, 9) forage crop, and 10) truck/garden crop. As you can see from the list, priorities had changed from 1974. Damage by wildlife to the resources shown in italics was not considered of major importance in 1974; in 1974 forestry was one of the most important resources in terms of damage, but by 1990 forestry issues had declined in importance; aircraft hazards from bird aircraft strikes had emerged as a major problem; damage to aquaculture had also become a problem as the aquaculture industry flourished and populations of depredating bird species [(such as cormorants (*Phalacrocorax auritus*)] soared. All of these issues became a large part of the research agenda for the DWRC in the 1990s.

The 1990 research needs assessment also provided a national ranking of animal species groups considered as problems by ADC state directors: 1) blackbirds (*Agelaius* spp.)/starlings, 2) waterfowl, 3) coyote/fox/dog, 4) wading bird/cormorant, 5) ungulate, 6) gull (*Larus* spp.), 7) beaver (*Castor canadensis*), 8) pigeon (*Columba livia*), 9) woodpecker, and 10) crow/raven (*Corvus* spp.). Some species remained of concern throughout the 25-year period; as in 1974, blackbirds and starlings were still of major importance. Other species groups causing damage changed since 1974, with damage by certain species not considered of major importance in 1974 but of considerable importance 25 years later; and mammalian predators, particularly coyotes, had dropped in importance from the number one species of concern down to number three. Conservation efforts for some species that had declined earlier in the 20th century have now been successful in bringing back populations of some formerly uncommon species, and some had become overly abundant by the 1990s. Certain species that were not common in 1974 were emerging as major nuisance species. Waterfowl were listed as the second-most-damaging species group; this reflects the growing problem of nonmigratory urban Canada geese, which were becoming prevalent in all areas of the U.S. by 1990. Wading birds and cormorants were listed as the fourth-most-damaging species, showing that the aquaculture industry was growing, cormorant populations were booming, and damage by predatory birds was suddenly of major importance. Ungulates were listed in fifth place because populations of white-tailed deer in the east were increasing in numbers and causing problems to suburban landscapes, to car collisions, and to human health through spread of Lyme disease; beavers were making a dramatic comeback from their near extinction in the early 1900s and were now causing considerable damage by flooding roads and other resources. By the 1990s the ADC program had changed dramatically, with many more personnel located in the eastern states to deal with the changing damage issues. Personnel were being located at airports to keep birds off of runways and out of flyways, and biologists were increasingly being asked to manage Canada goose, beaver, and ungulate problems within both rural and urban areas.

Another shift occurred in the 1990s that has greatly affected the field of wildlife damage management. In 1990 the Non-indigenous Aquatic Nuisance Prevention and Control Act was passed by Congress; it included the brown treesnake (*Boiga irregularis*) in the list of species covered by the bill. In 1996 the National Invasive Species Act was passed. These were the first of many laws dealing with invasive species issues, which formalized the important role of the WS/NWRC and other federal government institutions in research and management of invasive vertebrates. Researchers at the NWRC began to develop methods to manage invasive brown treesnakes, and WS developed a management program on Guam to reduce snake populations and deter them from emigrating to other Pacific Islands. Eventually toxicants, repellents, and trapping methods were developed that have kept the snakes from expanding to other islands and have allowed the reintroduction of some native birds on Guam. Important research has also taken place at the NWRC and elsewhere to register rodenticides for use in eradicating rats from offshore islands in an effort to restore seabird populations.

By the 1990s, changes had also occurred in the sociological and political landscape. The general public was increasingly concerned with animal welfare and was more interested in wildlife than ever before. Those trends led to a public preference for use of nonlethal methods

when managing wildlife and also led to increasing demand for more public involvement in wildlife management decisions. Wildlife Services and the NWRC responded to those public concerns. By the end of the decade, and with the completion of most of the reregistration requirements for WS pesticides, research at the NWRC went from a heavy emphasis on maintaining current pesticide registrations to increasing emphasis on development of nonlethal methods of managing wildlife damage. Since the mid-1990s, 75% or more of the NWRC budget each year has been devoted to nonlethal methods.

Emerging into the 21st century, we entered a new era: the age of computers and information. I have seen a growing trend in public involvement in wildlife management since the start of my career. And in the 21st century, with the use of the internet, it has become ever easier for the general public to access information; that public now wants to know everything a wildlife manager does and wants involvement in every action we take. Therefore, it became more important than ever that agencies be able to justify their management actions. Wildlife Services and NWRC responded by providing more information to the public and by putting more effort into evaluating risk versus benefit of management decisions. An economics project established by the NWRC during this time has provided managers with hard monetary and risk/benefit information on which to base management actions. It has also allowed WS operational personnel to comply with NEPA, which requires that environmental and human risks be examined before management actions can be taken.

In addition to conducting the 1990 Research Needs Assessment, the NWRC also hosted panels of experts to provide advice on ADC research needs. These panels were attended by personnel from a variety of groups, including personnel from state and federal wildlife agencies, universities, private industry, and animal welfare groups. A general recommendation of most of panels was to increase research on nonlethal methods. One of the specific recommendations, coming from the Association of Fish and Wildlife Agencies, was the need for development of a contraceptive for white-tailed deer and other overly abundant wildlife species. Based on this recommendation, a research project on wildlife contraceptives was begun in 1992 that has provided new tools for management of birds and mammals. An orally delivered pigeon contraceptive (OvoControl®) now registered with the EPA by Innolytics, Inc., was developed in collaboration with the NWRC (Fagerstone et al. 2008). In addition, a mammalian injectable immunocontraceptive (GonaCon) was developed by the NWRC and is currently registered for use in white-tailed deer and wild horses (*Equus caballus*) (Fagerstone et al. 2008). The NWRC has received numerous awards (including the Colorado Governor's Award) for the development of these innovative products. Reproductive control of wildlife has proven to be popular with the general public but has not been embraced as strongly by wildlife managers because of the high cost of its implementation and the slowness of the time frame over which populations are reduced (especially in long-lived species such as Canada geese and white-tailed deer). Thus, the wildlife damage management community is dealing with very contradictory goals at this time: dealing efficiently with increasing populations of overabundant species through lethal means, versus public wishes for more humane alternatives that may not be as efficient or cost-effective. This has led to an ever-increasing need for conflict resolution among wildlife management groups and the public.

In 2011, WS/NWRC undertook another research prioritization process (Tobin and Shwiff 2012). This newest survey focused on 3 areas: the resource sustaining the damage, the species causing the damage, and the tools and methods desired to manage the damage. The priority resource/problem areas (listed by highest number of WS respondents) were: aviation safety (15), disease (10), livestock predation (9), threatened and endangered species (7), crop depredations (6), habitat/resource protection (4), invasive species (4), aquaculture (2), human safety (2), dairies/feedlots (1), urban problems (1), big game (1), and forestry (1). As in the earlier surveys, livestock predation remains high on list, but other issues have eclipsed it in terms of importance. Aviation safety and wildlife disease issues are now at the top of the list, with disease appearing on the priority list for the first time; protection of threatened and endangered species and control of invasive species are also high on the research needs priority list for the first time. Human safety and urban wildlife problems are also becoming major issues. Forestry damage by wildlife, one of the top damage problems in 1974, is now on the bottom of the list. Aquaculture research has been reduced in priority, probably due to the decline of aquaculture ponds in the U.S. because of foreign competition and the high price of corn and other fish foods.

The species of concern also changed since 1974, and even since 1990. Priority species/species groups (with number of federal respondents) were: feral swine (24), coyotes/canids (23), beavers/nutria (13), blackbirds/ starlings (10), crows/ravens (6), geese (6), miscellaneous birds (5), vultures (5), snakes/herptiles (5), bears (3), raptors (3), deer (2), and cormorants (2). Invasive species show increasing importance based on this list: For the first time, feral swine appeared on the list of species of concern, and were on the top of the list. Coyotes/canids remained as one of the species most frequently mentioned, followed by beavers and blackbirds/starlings. Snakes (the brown treesnake and pythons) and other amphibians and reptiles appeared on the list as major species of concern for the first time. Cormorants were last on the list of priority species, again reflecting the fact that the aquaculture industry is suffering because of high corn prices and overseas competition.

The tools and methods listed by federal respondents as their top research priorities included the following (again, in priority order by the number of respondents listing that method): lethal control methods (24), repellents/nonlethal methods (22), economics (20), management techniques (19), impact assessments (19), ecological information (13), population monitoring/dynamics (12), vaccine development (4), reproductive inhibition (4), bait delivery methods (1), and genetics (1). Some of the

methods requested, such as lethal methods and repellents, have remained the same since 1974. Improved lethal methods topped the list of research needs, because the lethal tools used in the past are no longer registered in the U.S. or are increasingly viewed as inhumane. This research priority was followed closely by new or improved repellents and/or nonlethal techniques, showing that the general public is increasingly opposed to lethal control of problem animals and is willing to invest the time and money it requires to use alternative techniques to manage damage. Some new areas of nonlethal research needs emerged on this list since 1990. Managers are now requesting reproductive inhibition to control overabundant species, and genetics research is being requested to identify which species and animals are actually doing damage.

A large number of managers requested research that will help them meet the mandates of NEPA, which require assessing positive and negative impacts of federal management actions on public lands. Economics research was frequently requested to help managers decide on a best course of action by assessing the impacts of the problem and the cost-effectiveness of potential management methods. Also, managers expressed a need for ecological monitoring to help them develop risk/benefit analyses for management actions on public lands. In addition to helping managers, these risk assessment and economic damage assessment activities help researchers prioritize among the many competing issues that put demands on researchers' time and resources. Our research and development is increasingly being guided and evaluated through these activities.

One new area identified in the 2011 research needs survey was development of vaccines to deal with wildlife diseases. In the last 2 decades a big change that has occurred in the wildlife management profession, and in WS in particular, is an increased focus on zoonotic diseases: diseases that are spread from wildlife to humans or agricultural animals. Areas of WS management and research emphasis currently include West Nile virus, avian influenza, bovine tuberculosis, chronic wasting disease, crop safety (such as *E. coli* contamination), rabies, disease surveillance, and economics research. The new emphasis on disease is evident in the fact that feral swine were the top species listed as a problem in the U.S. In addition to the damage feral swine do to habitats, feral swine also cause disease. In some Texas sites up to 50% of swine are infected with Pseudorabies or Porcine Respiratory Syndrome virus, and they have been implicated in major crop contamination cases with enormous economic implications (Jay et al. 2007).

The research trends that I have discussed are evident in the topics covered in the *Proceedings* of the Vertebrate Pest Conference over the last 40 years (Table 4). Rodents have been a problem since 1972 and continue to be so. Problems with birds, predators, and pesticides peaked in the early 1990s, primarily as a result of FIFRA88 requirements, and increased research to maintain older pesticides and develop new tools as many older pesticides were no longer available. In the last decade there has been an increased emphasis on disease issues. And there has been a major increase in the number of papers dealing with invasive species.

FUTURE CHALLENGES

So, what challenges do we face in the future? One big challenge is that of changing world demographics. The population of the U.S. has increased from about 200 million in 1970 to over 300 million in 2010 and is estimated to be 363 million by the year 2030. The population of the U.S. is increasingly urban, with 80% of the population living in urban/suburban areas; this means that there are more wildlife damage issues as people spread outward from core city areas into suburbs and come into contact with wildlife. Also, the proportion of people engaged in hunting and fishing is gradually declining: in 1980 25% of the U.S. population fished and 10% hunted at least once a year; by 2006 this had declined to 13% of the population engaged in fishing, and only 5% in hunting. This increased urbanization prevents the use of lethal techniques like hunting, trapping, or toxicants for managing wildlife, and the urbanization and shift in recreational activities has led to a change in attitudes toward wildlife management: the urbanized public is more invested in management of "their" wildlife.

Along with increasing population and urbanization is an increasing emphasis on animal welfare. Other countries, particularly in Europe, place more emphasis on animal welfare than is currently done in the U.S. Currently in much of Europe it is not allowed to castrate male livestock without use of anesthesia. And lethal methods cannot be used to manage most species (with the exception of rats). In addition, research is restricted because of animal welfare concerns, such that even pulling or clipping a whisker from an animal for research purposes must be approved by an Institutional Animal

Table 4. Trends in topics in the Vertebrate Pest Conference Proceedings from 1972 to 2014.

Topic	1972	1974	1990	1992	1994	2010	2012	2014
Rodents	17	19	23	32	24	24	21	37
Birds	7	8	15	20	10	6	6	5
Predators	2	2	13	11	13	7	7	10
Pesticides	12	8	22	36	17	23	11	22
Disease	1	4	3	4	5	6	6	9
Invasives	4	2	3	5	5	18	15	60
Feral Hogs	-	1	1	1	-	4	1	10
Feral Cats	-	-	1	1	1	3	7	14
Island Systems	-	-	-	-	1	8	4	19

Care and Use Committee. In Great Britain, people have been known to abandon their houses rather than remove the European badgers (*Meles meles*) digging under the structure and threatening the stability of the house. In Australia and New Zealand, anticoagulant rodenticides are being portrayed as inhumane because of the prolonged time to death. Attitudes toward animal welfare are also changing rapidly in the U.S.: the public demands more use of nonlethal management methods, even if those methods are not as efficient as hunting, trapping, or use of toxicants. Wildlife managers are losing many of the lethal management options as state referendums limit the use of toxicants and leghold traps, so it is important to continue the research on safer, more humane pesticide alternatives and nonlethal means of managing wildlife populations.

As the world population increases and transportation becomes more efficient, the world becomes a smaller place, and there is more travel and trade; this means that it is ever easier for invasive species to be transported out of their original ranges. Estimates are that only 10% of the land on earth is more than 48 hours by plane travel from any point of origin on the planet, so the U.S. will be facing increasing threats from invasive species. The economic impact of invasive species on the U.S. economy is tremendous. Pimentel et al. (2010) estimated that invasive species cost the U.S. economy about $53 billion annually, which is about 0.4% of the gross domestic product and about 30% of the agricultural sector of the economy. Predictions are that invasive species will be more problematic in the future, and wildlife managers will be spending more time and money on their management.

Another challenge to wildlife managers comes with changing climates and global warming, which is predicted to allow diseases normally associated with tropical climates (malaria, encephalitis) and zoonotic diseases to spread to cooler regions of the globe. So wildlife managers need to be prepared for more outbreaks such as occurred with West Nile virus and bird flu. The goal of managers will be to prevent, detect, and respond to infectious-disease threats where they start, which can often be in association with wildlife.

MEETING THE CHALLENGES OF THE FUTURE

So, what lessons have I learned during my 40-year career that will help us meet the challenges the future will bring? One lesson learned is that strategic planning is critical to success for any project. In research, that planning needs to include both short-term and long-term goals. Wildlife managers naturally focus on the needs of the moment rather than on long-term goals. This is evident in the results of the NWRC's research needs assessments, where feedback generally has focused on short-term problems and solutions. While some research requests can be resolved fairly rapidly, such as providing an economic analysis or conducting a population assessment, fulfilling other research needs requires a long-term commitment of personnel and resources. An applied research center like NWRC has constant pressure to act as an extension service. While that is important, the mission of a research center is to look in the future at the shifting landscape of damage management and develop methods to meet those challenges; this means that researchers need to be good at predictions. In my experience, a research center needs to look 15 or 20 years into the future, which is frequently the amount of time it can take to research and develop an innovative new product. For example, research requested in 1992 on a deer contraceptive did not come to fruition with a product registered for use until 17 years later (Fagerstone et al. 2010). Also, a research center needs to balance the resources devoted to the "problem of the year" (a periodic disease outbreak or a rodent population explosion), which is of immediate importance to managers, with long-term needs. For example, damage by rodents continues to be one of the most economically important issues facing agriculture, yet development of new rodent control methods has not appeared on the research needs assessments as a major need.

Another lesson learned is that communication and collaboration are keys to being successful, both for managers and researchers. Communication both within and outside an agency is vital; communication within will allow those up and down the chain of command to have a common goal, will provide buy-in from personnel, and will increase the chances of long-term funding for a project. Collaborations among researchers within and outside of research organizations are increasingly important as budgets decline and as more areas of expertise are needed to develop more complex tools and methods. Communication outside research centers will ensure that the public is engaged and being listened to, thus building the necessary relationships that will ensure that once a tool is developed, it will actually be used. It is because WS and NWRC developed good communication with the EPA and with private industry through Consortia and partnerships that many toxicants, repellents, and contraceptive tools have been able to be registered and made available for use by managers and the public.

Finally, researchers in the wildlife damage management field need to be enablers. We no longer have the luxury of publishing manuscripts and expecting our findings to make their way into practical use without additional effort. Our stakeholders expect our research to be translated into techniques that will solve problems. This means that technology transfer is a necessary part of what a research center needs to accomplish. The key to success here is to set up a system that allows this to happen. At the NWRC a formal technology transfer manager position was established, a position I held for several years prior to my retirement. The basic researchers can now hand off ideas and proofs of concept to have them assessed for practicality and economic worth, and then to others in industry or management to reduce those ideas and techniques to practice. This is not a trivial pursuit. It may mean hosting workshops or open houses to highlight techniques that can be used by managers. It may also mean patenting ideas to preserve their value, so a private company can license the technology and make a profit by manufacturing a product without competition. Technology transfer takes time, but it provides value to research that cannot be achieved in any other way, and it will be of increasing importance in

the future.

In summary, difficult objectives can be met given motivated people, adequate funding, and persistence. And the NWRC, Wildlife Services, and the whole wildlife damage management community are full of highly motivated, creative people. Creativity and collaboration can provide solutions; for example, creativity and collaboration in developing private industry/government partnerships provided funding for reregistration of strychnine, zinc phosphide, and DRC-1339, and allowed development of wildlife contraceptives. Researchers increasingly need to transfer research and technologies into practice, because while knowledge is wonderful –useful knowledge is even better! Above all, researchers and wildlife managers need to have a sense of humor. Your career will not go where you expect it to, but it can go in very rewarding directions if you embrace the changes and challenges that will come.

LITERATURE CITED

Fagerstone, K. A. 1990. Politics and economics of maintaining pesticide registrations. Proc. Vertebr. Pest Conf. 14:8-11.

Fagerstone, K. A., and P. L. Hegdal. 1998. Risk assessment of rodenticides through use of telemetry and other methods: 5 examples. Ch. 6 (Pp. 49-66) *in*: Radiotelemetry Applications for Wildlife Toxicology Field Studies. SETAC Press, Pensacola, FL.

Fagerstone, K. A., and G. Keirn. 2011. Wildlife Services–A leader in developing tools and techniques for managing carnivores. Proc. Wildl. Damage Manage. Conf. 14:44-55.

Fagerstone, K. A., L. A. Miller, J. D. Eisemann, J. R. O'Hare, and J. P. Gionfriddo. 2008. Registration of wildlife contraceptives in the United States of America, with OvoControl and GonaCon immunocontraceptive vaccines as examples. Wildl. Res. 34:586:592.

Fagerstone, K. A., L. A. Miller, G. Killian, and C. A. Yoder. 2010. Review of issues concerning the use of reproductive inhibitors, with particular emphasis on resolving human-wildlife conflicts in North America. Integr. Zool. 1:15-30.

Jay, M. T., M. Cooley, D. Carychao, G. W. Wiscomb, R. A. Sweitzer, L. Crawford-Miksza, D. K. Lau, J. O'Connell, A. Millington, R. V. Asmundson, E. R. Atwill, and R. E. Mandrell. 2007. *Escherichia coli* 0157:H7 in feral swine near spinach fields and cattle, central California coast. Emerg. Infect. Dis. 13:1908-1911.

Packham, C. J., and G. Connolly. 1992. Control methods research priorities for Animal Damage Control. Proc. Vertebr. Pest Conf. 15:12-16.

Ramey, C. A., E. W. Schafer, Jr., K. A. Fagerstone, and S. D. Palmateer. 1992. Back to the future for APHIS's vertebrate pesticides. Proc. Vertebr. Pest Conf. 15:17-21.

Smith, R. 1974. Animal damage control research – Are present priorities based on actual need? Proc. Vertebr. Pest Conf. 6:82-84.

Tobin, M. E., and S. E. Shwiff. 2012. Wildlife Services 2011 research needs assessment. Proc. Vertebr. Pest Conf. 25: 308-314.