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The Introduction, Impacts, And Management of a Large, Invasive, Aquatic Rodent In The United States

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Chapter 2

THE INTRODUCTION, IMPACTS, AND MANAGEMENT OF A LARGE, INVASIVE, AQUATIC RODENT IN THE UNITED STATES

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INTRODUCTION

Marshes, both tidal and non-tidal, are productive and complex ecosystems. The water in these systems ranges from fresh, to brackish, to saline as one moves from inland to coastal areas. Marshes are an interface between upland and aquatic habitats, and many biotic and abiotic processes lead to increased species richness and diversity (Gedan et al., 2009). Marshes provide many ecological services, including recharge and discharge of ground water; water quality control; retention, removal, and transformation of nutrients; habitats for many floral and faunal species; biomass production and exports; flood control and storm buffering; and stabilization of sediments and slowing of erosion (Southwick Associates, 2004; Woodward et al., 2001). Marshes also provide for human activities such as hiking, wildlife viewing, hunting,

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trapping, fishing, etc. (Bounds and Carowan, 2000; Southwick Associates, 2004).

Marshes in North America, and elsewhere in many parts of the world, have been greatly affected by human activities, including dredging, filling, water diversions, flood control structures, contamination by pollutants, conversion to agricultural cropland and urban centers, introduction of invasive species, salinization, habitat fragmentation, and other factors (Bounds and Carowan, 2000; Takekawa et al., 2006; Pathikonda et al., 2008; McFalls et al., 2010). Sea level rise and hurricanes also affect marshes and species interactions (Pathikonda et al., 2008; Pyke et al., 2008). Additionally, many marshes have been invaded by exotic species, upsetting normal physical and ecological functions, species richness, and species interactions. Much has been studied and published about invasive plants invading marshes (e.g., Guntenspergen and Nordby, 2006; Pathikonda et al., 2008), but much less has been reported about invasive herbivore impacts in marshes.

Nutria, or coypu (*Myocastor coypus*), are semi-aquatic rodents native to southern South America. In the first half of the 20th century, nutria were widely promoted as a farmable fur bearer and introduced to more than 20 US states, beginning in California in 1899 (Carter and Leonard, 2002). Through a series of accidental and intentional releases, to establish fur resources or to control aquatic weeds, feral populations have since become established in 17 states and are considered an invasive species causing detrimental impacts to native habitats, agricultural resources, and water control structures. In the United States, nutria impacts have mainly occurred in the mid-Atlantic, Southeast, and Pacific Northwest regions of the country. The feeding activities of these herbivores can damage agricultural crops and aquatic vegetation, leading to altered aquatic ecosystems. Their burrowing habits can weaken water control structures, and they are a host for some infectious diseases.

Management of nutria and the damage they cause can be problematic for natural resource managers. Nutria are habitat generalists, prolific breeders, and are capable of long-distance dispersals – all characteristics of successful invaders. Eradication or local extirpation may be feasible and desirable in areas where risk of reinvasion can be minimized, but a number of challenging criteria must be met for eradication efforts to succeed. However, in contiguously occupied habitats, control through population suppression may be the only viable alternative for protecting high priority resources. Both management strategies are labor intensive and require specialized equipment to reach nutria populations in wetland environments with limited access. Control efforts can be further complicated where nutria are considered a

valuable resource and regulated harvest occurs, such as in Louisiana. In this chapter, we will discuss nutria biology, ecology, introductions, impacts as an invasive species, and management and eradication efforts.

NUTRIA BIOLOGY, ECOLOGY, AND BEHAVIOR

Nutria are semi-aquatic rodents that have stout, highly arched bodies with a large head and a long rat-like tail sparsely covered with bristly hairs (Figure 1). Adults typically weigh between 5-7 kilograms, and males are slightly larger than females. The front feet have four non-webbed digits that are used for digging and feeding on vegetation. The hind feet have 5 digits and four are webbed, making nutria efficient swimmers. Other aquatic adaptations include eyes set near the top of the head and a valvular nose and mouth, allowing individuals to stay underwater for several minutes (LeBlanc, 1994). The fur consists of a dense reddish-brown to yellowish-brown outer coat containing long, coarse bristles (guard hairs). The under coat is dense and dark gray. The large, ever-growing incisors are distinctly orange colored. Nutria have conspicuous white whiskers and fur around their mouth, a distinguishing feature when compared to other aquatic mammals (e.g., muskrat, beaver). They have a hunched appearance when on land, but are agile enough to quickly retreat to the water when sensing danger using advanced auditory and olfactory senses.

Figure 1. A foraging nutria (*Myocastor coypus*).

The primary habitat for nutria is freshwater marshes, but populations are able to persist in a variety of slow-flowing aquatic systems, including lakes, ponds, swamps, drainage canals, rivers, and streams (LeBlanc, 1994). Home ranges are typically less than 10 ha, but much larger home ranges have been reported (Nolfo-Clements, 2009). Individuals generally stay within a few hundred meters of their burrows, but daily movements up to 3.2 km have been documented (Linscombe et al., 1981). Populations can become quite dense, reaching 25 nutria per ha. Nutria usually remain in their original home range area throughout their lives, however, they may disperse up to 80 km due to cold weather or drought conditions (Woods et al., 1992). Dispersal is typically through aquatic corridors, but nutria can also disperse across land when necessary.

Nutria form social groups and utilize a polygynous mating system. Groups consist of several adult females, a dominant male, and juveniles of both sexes. Female nutria are polyestrous and can reach sexual maturity within six months. They are non-seasonal breeders capable of producing 3 litters a year with an average of 4 to 5 kits per litter (Bounds et al., 2003). Gestation is approximately 130-132 days (LeBlanc 1994). The young are precocial and able to swim and consume vegetation within a few days of being born. Sub-adult males are often driven from the group by the dominant males (Gosling, 1977). Average lifespan is about 3 years with annual mortality rates of 53-74% (Chapman et al., 1978).

Nutria are primarily nocturnal, although they can be frequently seen during the day. Daytime feeding activity may increase during winter months to conserve energy (Gosling et al., 1980). Their main activities involve feeding, grooming, and sleeping. Nutria sometimes live in burrows which they make themselves or usurp from other animals. Generally, burrows have multiple entrances near the water line. Burrows may be up to 15 m in length and may be simple or somewhat complex (Nowak, 1999). Nutria also build elevated feeding and resting platforms out of aquatic vegetation. Runs or slides at the water's edge are created where nutria repeatedly exit the water to feed. These modifications can substantially impact vegetative communities (Evans, 1970; Kinler et al., 1987), as clearing of vegetation by nutria may alter plant succession and convert marsh ecosystems to more open-water environments.

Nutria are voracious consumers of vegetation and known to completely denude vegetation from areas where they feed before moving to another area (Mach, 2002). Nutria prefer the basal portion of plants and they can consume up to 25% of their body weight in vegetation daily (Hutchins et al., 2004). Other researchers have noted that nutria are also wasteful feeders with as much

as 90% of damaged plant material not consumed when they forage on belowground roots and tubers (Taylor and Grace, 1995), which is common during the winter months. Nutria show preference for certain plant species, resulting in over-utilization of these species, but diet is also adjusted seasonally based on food availability (Borgnia et al., 2000). Nutria also feed occasionally on mussels and other invertebrates (LeBlanc, 1994; Hutchins et al., 2004).

NUTRIA IN THEIR NATIVE RANGE

Nutria, known as coypu outside of the US, are native to a large area of southern South America. Their range extends from southern Brazil and Peru down through Bolivia, Uruguay, Paraguay, Argentina, and Chile. Their range, biology, ecology, and history of introductions have been reviewed by Woods et al. (1992), Lever (1995), Nowak (1999), Carter and Leonard (2002), Long (2003), and Hutchins et al. (2004), and we draw from those sources for materials presented in this and the next section. Native nutria populations generally inhabit low elevation freshwater wetlands, marshes, and rivers. However, they have been found at 1,190 m elevations and in brackish and salt water systems in Chile (Woods et al., 1992). Few scientific studies of nutria in their native range were published in the past, but a relatively large volume of scientific literature has been published in recent years (e.g., Borgnia et al., 2000; Guichón and Cassini, 2005; Guichón et al., 2003a,b,c; Guichón and Cassini, 2005; Corriale et al., 2006; Martino et al., 2008; Gayo et al., 2011).

Much of the nutria research in their native range has been on social structure and life history. They may live in pairs, but often form colonies of 10 or more individuals consisting of related adult females, a dominant male, and juveniles of both sexes (Guichón et al., 2003a). Guichón et al. (2003a) also documented high group fidelity and reported interactions and cooperative behaviors such as nursing in groups, allo-grooming, and alarm calls within groups. In their native range, the main predators are jaguars (*Felis onca*), mountain lions (*F. concolor*), ocelots (*F. pardalis*), little spotted cats (*F. tigrinus*), and caimans (*Caiman* spp.) (Woods et al. 1992). Nutria are also affected by a large number of disease agents and parasites (Woods et al. 1992, Martino and Stanchi, 1994; Gayo et al., 2011). Martino et al. (2008) necropsied nutria from 4 areas of Argentina and found the most common mortality factors, in declining order, to be: trauma (predation or vehicle-killed), poisoning by various toxins, starvation, infectious diseases, and

miscellaneous causes. As might be expected, mortality (12-55%) is lower in protected areas of Argentina (Guichón et al. 2003c).

In agro-ecosystems of Argentina, nutria feed preferentially on aquatic monocots (40-60% of the diet) (Borgnia et al., 2000). In contrast, terrestrial monocots comprised 30-35% of the diet and were consumed in proportion to their availability. Nutria consumed dicots (0-15% of the diet) significantly less than their availability. Borgnia et al. (2000) also reported that the most preferred monocots were *Eleocharis bonariensis* in the winter and spring and *Lemna* species in the summer and fall. It appears that the preference of nutria for aquatic vegetation versus terrestrial vegetation is not related to nutritional content of the plants, but probably because predation risk is lower when they feed in or near water (Guichón et al., 2003b). These authors also noted that less than 2% of the 6 crops grown in the area were consumed by nutria and that they were unlikely to cause significant crop damage if a narrow fringe of native vegetation along riparian systems was left as a buffer.

In their native range, nutria have historically been heavily exploited for their plush fur, as a source of food, and occasionally kept as pets to supply the fur, food, and pet trades (Guichón and Cassini, 2005). They are also considered a pest species, although research suggests otherwise. Grazing damage in urban areas has been documented (Corriale et al., 2006), but the social perception of nutria as an agricultural pest species is not supported by research (Guichón and Cassini, 1999). As a result of exploitation and pest control efforts, nutria densities are rather low in areas of Argentina (Guichón and Cassini, 2005) and other parts of South America. As a conservation measure, authorities began regulating harvests and established protected reserves in the 1990s where no harvesting is allowed (Nowak, 1999; Guichón et al., 2003c). Additionally, captive breeding farms have been established to provide a continuous supply of pelts and meat while relieving pressure on wild populations.

Worldwide Nutria Introductions

Nutria have been introduced to many countries around the world, including Canada, Great Britain, Ireland, Norway, Finland, Belgium, Netherlands, Denmark, France, Germany, Austria, Switzerland, Bulgaria, Czech Republic, Slovakia, Poland, Romania, Italy, Greece, Yugoslavia, Russian Federation, Asia, Israel, Turkey, Thailand, China, South Korea, Japan, Kenya, Tanzania, Zambia, Zimbabwe, and Botswana. Background on these

introductions was compiled by Lever (1985), Carter and Leonard (2002), and Long (2003). The introductions occurred between the years of 1882 (France) and 1967 (Switzerland) (Carter and Leonard, 2002). Most of the introductions were escapes or releases from captive populations being bred for their fur, although in some cases, nutria spread from initial introductions in neighboring countries. Nutria never became established or became extinct in several countries: Kenya, Zambia, Zimbabwe, Botswana, Thailand, Denmark, Norway, Finland, Ireland, Spain, and Sweden. Dry or cold conditions probably were responsible for most of these failures.

Although often considered a valuable resource, in many of the introductions feral nutria became a serious pest, damaging crops, marsh systems, and water control structures. These feral populations also pose a disease hazard (Gosling and Baker, 1989). Efforts to eliminate or greatly reduce feral nutria populations using trapping, shooting, and poisons have resulted in varying levels of success. Generally, an intensive and sustained trapping effort is needed to achieve success and often requires incentive payments to trappers to maintain a high level of trapping effort, especially when population densities decline. This approach resulted in the successful eradication of feral nutria in England in 1989 (Gosling, 1989; Gosling and Baker, 1989). Government intervention and support, along with substantial population biology research, were important aspects of the successful eradication (Sheal, 2003).

Outside of the United States and England, much of the recently published scientific literature on introduced nutria originates from Italy. Nutria became established in Italy between 1960 and 1970 after escaping from fur farms (Reggiani et al., 1995). These authors studied the population dynamics of nutria in a 37.5 ha plot within a nature preserve in central Italy. Based on mark-recapture methods, they estimated that the population size varied from 27-137 individuals between 1989 and 1991. The population trend was decreasing numbers in the winter and increasing numbers from summer to winter. They also noted that the population remained fairly stable through mild winters, but that reproductive activity and recruitment were generally high after colder winters. Density-dependent factors such as pregnancy failure and newborn losses were important in the population's dynamics. These findings were similar to those of Gosling et al. (1983) and provide evidence that sustained cold winters are a main limiting factor for nutria distribution in non-native habitats.

Prigioni et al. (2005a) studied the food habits of nutria in northwestern Italy and found that aquatic macrophytes provided the majority (81.8%) of the

diet year round. Nutria fed mostly in the water, but also fed on terrestrial vegetation near water (especially young nutria). While they noted that only slight damage to vegetation occurred, they warned that some sensitive aquatic plants species could suffer long-term damage. These results, along with findings from England (Ellis, 1963) and the US (Wilsey et al., 1991), demonstrate that nutria in non-native environments are generalist herbivores and can utilize a variety of food resources depending on availability.

Panzacchi et al. (2007) estimated that between 1995 and 2000, nutria caused about 11,631,721 euros of damage in Italy and control activities cost about 2,614,408 euros. More than 220,000 nutria were removed through control programs during this time period. They projected that nutria range in Italy may expand 2.5-3.3 times and that economic losses may reach 9-12 million euros per year. While nutria can be successfully trapped with periodic trapping sessions, populations can quickly rebound (through births and immigration), hence long-term reductions have not resulted from trapping programs (Prigioni et al., 2005b; Panzacchi et al., 2007; Cocchi and Riga, 2008). This confirms what was learned in England: that only a very intensive and sustained trapping effort can reduce or eliminate introduced nutria populations. Panzacchi et al. (2007) also suggested that although the nutria eradication in England was very costly (5 million euros over 11 years), that approach may still have a more positive cost-benefit ratio in the long-term compared with the permanent control program in Italy (14 million euros spent over only 6 years).

A few other interesting findings have come from nutria studies in Europe. Meyer et al. (2005) noted that introduced nutria in urban areas of Germany are often diurnal (not nocturnal as in their native range), feeding on foods provided by humans. In France, Waterkeyn et al. (2010) studied the occurrence of freshwater invertebrates in the fur of introduced nutria. They retrieved more than 800 invertebrates representing 14 different taxa from the fur of 10 nutria. They concluded that in addition to vegetation and digging damage, nutria may alter invertebrate communities by introducing new species or genotypes to water bodies in which they did not originally occur.

Nutria Introductions in the United States

The introduction, natural history, value, management, and impacts of the nutria in the United States have been described in detail (Evans, 1970; Willner, 1982; Kinler et al., 1987; Bounds et al., 2003). Nutria were first introduced

into the United States in 1899 to establish a fur farm in California, but this initial introduction failed due to lack of reproductive success (Ashbrook, 1948). During the 1930s, nutria were imported for fur farms in Louisiana, Ohio, New Mexico, Washington, Michigan, Oregon, and Utah (Kinler et al., 1987). In addition, nutria were promoted as controllers of nuisance aquatic vegetation (such as water hyacinth, *Eichhornia crassipes*, and alligator weed, *Alternanthera philoxeroides*) and were rapidly introduced in the Southeast in the 1930s and 1940s (Evans, 1970). Since then, accidental and intentional releases have permitted nutria to become established in at least 15 states (Figure 2) (Willner, 1982), with the highest densities occurring along the Gulf Coast of Louisiana and Texas (LeBlanc 1994). The introductions of nutria have been summarized by Carter and Leonard (2002) and Long (2003). The main limiting factor for the spread of nutria in North America seems to be the severity of minimum winter temperatures (Sheffels and Sytsma, 2007).

IMPACTS BY INTRODUCED NUTRIA

Agriculture. Impacts by nutria to agriculture include foraging on crops, weakening irrigation structures by digging burrows, and potential disease transmission to livestock.

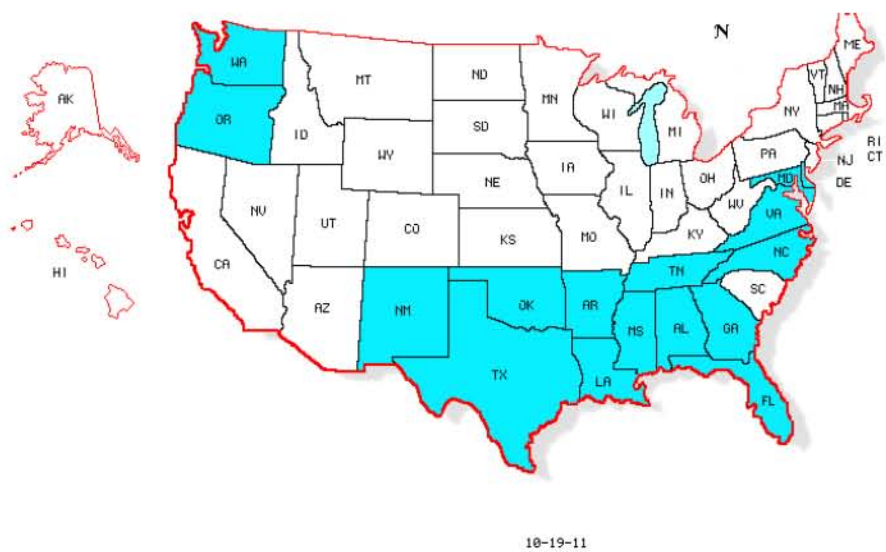

Figure 2. US states (shaded) with established nutria populations.

Crop damage is most prevalent in areas adjacent to aquatic habitats supporting nutria, and especially where nutria are abundant (Bounds et al., 2003). The primary crops damaged by nutria in the United States are sugarcane and rice, but others include corn, milo (grain sorghum), sugar and table beets, alfalfa, wheat, barley, oats, peanuts, and various melons and vegetables (LeBlanc, 1994). In Louisiana, nutria commonly undermine and break through water-retaining levees in flooded fields used for rice and crawfish production (LeBlanc, 1994). Nutria can be infected with pathogens (e.g., leptospirosis) and parasites transmissible to livestock, which is especially a concern in situations where livestock drink from water contaminated by nutria urine and feces (LeBlanc, 1994).

Erosion. In addition to compromising agricultural water control structures, nutria burrowing activity can weaken flood control levees that protect low-lying areas, as well as roadbeds and dikes (LeBlanc, 1994). Weakened banks can cave in under heavy weight, posing serious risks to heavy equipment operators. Erosion impacts are particularly costly in developed areas where infrastructure is compromised. Nutria burrowing can also result in substantial erosion of natural stream banks. This results in large amounts of sediment entering the stream system and subsequent water quality impacts (Sheffels and Sytsma, 2007), which are of particular concern in areas being managed to preserve sensitive aquatic species.

Disease Transmission. Numerous diseases have been identified in nutria (Pridham et al., 1966; Howerth et al., 1994; LeBlanc, 1994; Bounds et al., 2003). Transmission of diseases and parasites from nutria to humans is not well-documented, but could potentially involve toxoplasma, chlamydia, salmonella, and other diseases (Bounds et al., 2003). Diseases are common in captive populations where high densities of nutria are housed in close proximity and cleaning standards are low (Bounds et al., 2003). In turn, these conditions pose the greatest risk to human handlers who do not wear appropriate personal protective equipment such as gloves while handling animals, or masks while cleaning pens. Nutria parasites most often transmitted to humans are nematodes and blood flukes (*Strongyloides myopotami* and *Schistosoma mansoni*) that cause what is commonly known as "swimmer's itch" (LeBlanc, 1994).

Native Vegetation. Nutria in high densities also can be detrimental to coastal and inland marshes and other riverine and wetland areas. Nutria are recognized as at least a contributing factor to the decline of native Louisiana coastal marsh, declining vegetative biomass, and changing plant communities (Shaffer et al., 1992; Grace and Ford, 1996; Evers et al., 1998). Louisiana has

lost about 22,000 acres of marsh to nutria vegetative damage and over 100,000 acres of marsh have been negatively impacted by nutria (Marx et al., 2004). In Maryland, nutria are considered a primary factor in the decline of the marsh in the Delmarva Peninsula due to their "eat out" of the vegetative root mat. The vegetative root mat is a floating marsh above a layer of fluid mud. Nutria will chew through the mat, which exposes the mud and leads to erosion caused by tidal currents and wave action. Erosion causes sinking of the marsh surface, which results in vegetation loss to flooding. The areas damaged by nutria can become permanent, open water ponds (Figure 3). Much of this marsh loss removes habitat for native wildlife species such as waterfowl, wading birds, and muskrats. Marsh damage by introduced nutria in the United States is considered in more detail in the case studies below.

Competition with Native Muskrats. Native muskrats (*Ondatra zibethicus*) are widespread in North America and have contributed substantially to the fur industry in the United States since the colonial times (Erb and Perry, 2003). Nutria and muskrats co-exist in numerous areas, but it is surmised that the much larger, exotic nutria can out-compete muskrats. This may have contributed to declines in muskrat populations observed in various parts of the United States (Evans, 1970; Lowery, 1974; Genesis Laboratories, Inc., 2002). Anecdotal evidence suggests nutria and muskrats may compete for food, resting platform sites, and den sites. Nutria have also been observed attacking muskrats confined in traps, suggesting nutria are a more dominant species (Lowery, 1974).

Figure 3. (Continued).

Figure 3. Nutria damage to marsh vegetation at the Blackwater National Wildlife Refuge, Maryland. The top photograph was taken in 1938; the bottom photograph was of the same area in 1989.

Regional Case Studies

Southeastern United States: Louisiana. Nutria were introduced to Louisiana in the 1930s for fur farming, a growing industry in many parts of the United States. As with other states, some animals escaped (especially during flooding or storm events) and some were intentionally released. They first became established in the western coastal marsh areas, but later spread eastward. Nutria are found in freshwater, brackish water, and salt water marshes, although most harvested nutria are taken from freshwater marshes (Jordan and Mouton, 2010). By the mid-1950s, muskrat numbers were declining, nutria populations were still expanding, and farmers began to report serious rice damage in southwestern Louisiana and sugarcane damage in southeastern Louisiana. By the late 1950s, it was estimated that 20 million nutria occupied coastal Louisiana (Genesis Laboratories, Inc., 2002). In 1958, Louisiana placed nutria on the unprotected species list and put a $0.25 bounty on each nutria harvested in several south Louisiana parishes. However, funds were never provided for the bounty.

The history of nutria markets, both values and harvests, has been nicely summarized by Jordan and Mouton (2010) and Genesis Laboratories, Inc. (2002). The Louisiana Department of Wildlife and Fisheries (LDWF) began working toward development of a nutria fur market, which began to grow slowly in the 1960s due to a demand in the German fur industry. In the 1950s, about a half million nutria per year were being harvested (Figure 4). Fur prices continued to rise, and the harvest grew steadily with annual harvests of over one million from 1961-1980. In 1962, the nutria harvest surpassed the muskrat harvest, becoming the backbone of the Louisiana fur industry.

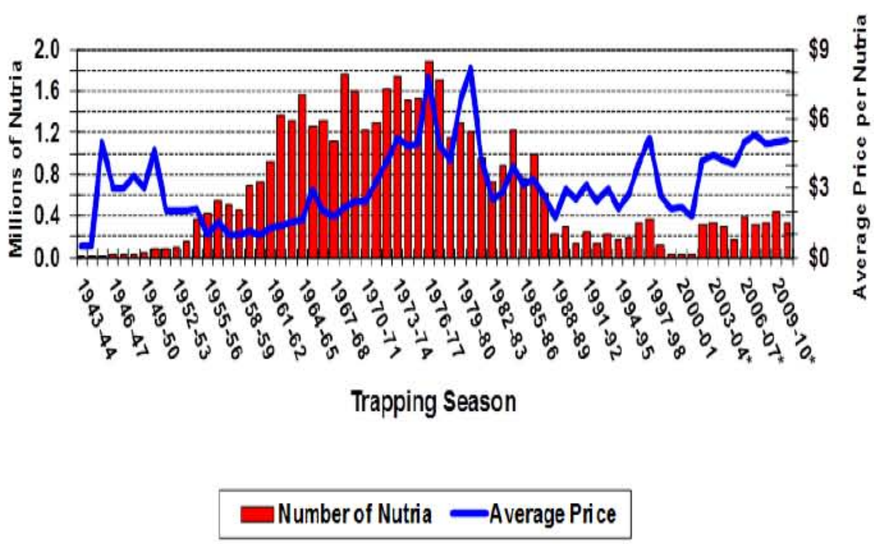

Figure 4. Nutria harvests and prices in Louisiana, 1943-2010 (courtesy of Edmond Mouton, Louisiana Department of Wildlife and Fisheries).

In 1965, the state returned nutria to the protected species list with regulated harvests. Between 1971 and 1981, the average annual value of harvested nutria to coastal trappers was $8.1 million. The peak nutria harvest occurred in 1976 with a value of $15.7 million to coastal trappers. After several years of declining fur value and nutria harvests, the Russian fur demand increased, resulting in increased fur value and nutria harvests in Louisiana. The increased harvests were still well below the annual harvests of the 1970s and early 1980s, however, and it was short-lived as the Russian economy collapsed. Nutria harvests plummeted and the 1999-2000 trapping season resulted in only 29,544 pelts taken.

As a result of the low harvests, nutria populations increased rapidly, as did damage complaints starting in 1987 and becoming frequent in the early 1990s. The LDWF began aerial surveys of nutria damage in southeastern Louisiana in the early 1990s. Between 1993 and 1996, the acres of damaged marshland increased from 45,000 acres to 80,000 acres. More extensive surveys began with funding from the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA), which revealed areas covering about 90,000 acres damaged by herbivory. By 1999, this figure had increased to nearly 105,000 acres.

The marsh vegetation damage in Louisiana has been studied since at least the 1950s, and it is a dynamic process with many factors. Carter et al. (1999) created an extensive model that demonstrated the relationships between nutria population dynamics, vegetation removal, and biomass and acreage of marsh vegetation were complex. Ford and Grace (1998) studied the effects of fire and herbivory and found both to substantially reduce plant biomass. Plots fenced to exclude herbivores, but also burned, had greater plant species richness.

Research on the specific role of nutria herbivory in marsh decline has intensified as concerns about declining marsh acreage have grown. Many of the studies have made use of exclosures to measure nutria herbivory impacts. Harris and Webert (1962) were among the first to study nutria herbivory in Louisiana and found that the most damaged marsh vegetation species was big cordgrass (*Spartina cynosuroides*). Fuller et al. (1985) noted that exclusion of nutria from islands may be necessary for the re-establishment of vegetation after severe flooding events. More recently, Wilsey et al. (1991) demonstrated that nutria diets were comprised of a variety of plant species, but that certain species dominated (i.e., were highly preferred even when at low coverage levels). They also noted that the nutria diet varied between seasons. Taylor and Grace (1995) reported that nutria reduced plant biomass by as much as 30%, but that plant species richness was unaffected. However, Evers et al. (1998) concluded that nutria herbivory affected both plant biomass and plant species composition. Johnson and Foote (2005) reported that nutria foraging greatly reduced annual above ground plant production and that nutria fed heavily on *Spartina patens*. Geho et al. (2007) also reported substantial reductions in plant biomass due to nutria foraging and noted that nutria fed heavily on *Taxodium distichum* and *Typhus domingensis*.

Methods to restore marsh vegetation damage caused directly by nutria in Louisiana have been studied as well. Conner and Toliver (1987) studied methods to protect the restoration efforts of baldcypress (*Taxodium distichum*) in Louisiana that were commonly thwarted by nutria foraging. They found that the use of plastic Vexar® tubing around the seedlings did not provide

protection from nutria, but chicken wire barriers did provide adequate protection. Llewellyn and Shaffer (1993) suggested that *Justicia lanceolata* be used to restore marsh vegetation because the plant is not a preferred food of nutria. McFalls et al. (2010) found that fertilizer addition increased plant biomass, but was most effective when nutria populations were reduced or excluded.

Despite these impacts, nutria are still considered an important resource in Louisiana, providing both income and recreation for hunters and trappers. They also help provide a prey base for alligators, another valuable resource in the state (Joanen et al., 1997; Gabrey et al., 2009). Hence, Louisiana has not opted for the eradication approach to feral nutria populations that Maryland and some western states have pursued. Nutria densities still need to be reduced to protect coastal marshes, so LDWF has pursued two approaches to accomplish that goal.

The first approach was to market nutria as a healthy alternative for human consumption, providing recipes on-line (www.nutria.com/site14.php) and in brochures (Kinler, undated). Nutria have just 1.5 g fat per 100 g of meat, compared to turkey with 2.9 g and beef with 26.6 g. Nutria also have a high protein level of 22.1 g per 100 g, compared to turkey with 21.8 g and beef with 16.6 g (Kinler, undated; Saadoum et al., 2006). Unfortunately, not much of a market for nutria meat ever developed.

The second approach to reducing nutria densities involved implementing a nutria control incentive program in 2002 (Jordan and Mouton, 2010). Funding for a Coastwide Nutria Control Program (CNCP) has been provided by the Coastal Wetlands Planning, Protection and Restoration Act through the Natural Resources Conservation Service and the Office of Coastal Protection and Restoration. The goal of the CNCP is to significantly reduce damage to coastal wetlands caused by nutria by removing 400,000 nutria annually. The LDWF administers the program through the following activities:

- Conduct and review the registration of participants in the program;
- Establish collection stations across coastal Louisiana;
- Count valid nutria tails and present participants with a receipt or voucher;
- Deliver tails to an approved disposal facility and receive documentation that nutria will be properly disposed of and will not leave the facility, and;
- Process and maintain records regarding participants as well as the number and location where tails were collected.

An incentive payment to registered trappers and hunters started at $4.00 per tail and in 2003-2004 a total of 332,596 nutria tails were collected by 346 participants under the CNCP. Because the harvest began to decline after the first few years, the incentive payment was raised to $5.00 in the 2006-2007 trapping season (Jordan and Mouton, 2010). The 2009-2010 trapping season had 306 participants who harvested 445,963 nutria and received $2,229,815 in incentive payments (Jordan and Mouton, 2010). Hence, the program has been achieving its goal of harvesting about 400,000 nutria per year. A majority of nutria were killed with firearms (61%), while 39% were trapped.

The CNCP continues to conduct annual aerial vegetation surveys following nutria harvests to assess damaged marsh acreage. Damaged acreage ranged from 79,444 to 97,271 acres before implementation of the CNCP incentive payments. Since implementation of the CNCP in 2002, annual damaged acreage has declined steadily from 82,080 acres in 2003, down to 55,755 acres in 2006, and only 8,475 acres in 2010. Additionally, it has been shown that marsh habitat can recover in the absence of nutria or with lower population densities of nutria. The amount of conversion of marsh vegetation to open water has also declined as marshes recover.

Northeastern United States: Maryland. The emergent wetlands of Maryland's Chesapeake Bay at one time covered about 205,815 acres (Southwick Associates, 2004). The Blackwater National Wildlife Refuge (NWR) is comprised of over 25,000 acres on the Delmarva Peninsula, including about 13,000 acres of coastal marshland. The refuge was established to protect and manage habitat for migratory birds, threatened and endangered flora and fauna, and other native species. Preservation activities include 1) administering prescribed burns on parts of the 13,000 acres of marshlands to improve marsh and forest habitats, 2) managing 650 acres of croplands to diversify the wildlife habitat, 3) managing 27 freshwater impoundments totaling 850 acres to provide resting and feeding habitat for migrating birds, 4) managing forest habitats for the endangered Delmarva fox squirrel, 5) administering a trapping program to manage furbearer populations, 6) controlling invasive species to protect native species, and 7) conducting research to improve management decision-making. The refuge and surrounding area is used for commercial and recreational fishing, clam and shellfish harvest, furbearer trapping, wildlife viewing, and other outdoor recreational activities. It has been estimated that the refuge is visited by 500,000 people each year, generating at least $15 million for the local economy (Bounds and Carowan, 2000).

Nutria were introduced into the Delmarva Peninsula of Maryland in 1943 (although possibly as early as late 1930s) to bolster the fur industry (Willner et al., 1979). Initially, they were raised in captivity on fur farms, but eventually some nutria escaped and/or were purposefully released when captive-rearing proved unprofitable (Bounds and Mollett, 2000). They spread rapidly, and severe damage to some areas of marsh was noticed as early as 1970 (Willner et al., 1979). It was estimated that the Blackwater NWR had between 35,000 and 50,000 nutria, but only about 20% or less were harvested each year (Bounds and Mollett, 2000). Densities ranged from 2.7-16.0 nutria per ha (Willner et al., 1979). Damage was especially heavy in marsh areas dominated by Olney 3-square bulrush (*Scirpus olneyi*), which formed over 80% of the nutria diet (Willner et al., 1979).

Over 7,000 acres of the refuge's 13,000 acres of marshland has been severely damaged to date, resulting in extensive ecological and economic impacts. Nutria feed heavily on the roots and stems of marsh plants and relatively little on the leaves or on algae (Willner et al., 1979). When nutria excavate roots, the submerged root mat is disturbed and sediments are exposed and subjected to tidal erosion and conversion to open water (M. Haramis and R. Colona, USDI Geological Survey, unpubl. data). An economic assessment on the impacts of overabundant nutria populations in Chesapeake Bay was conducted for the Maryland Department of Natural Resources (Southwick Associates, 2004). The researchers reported that the current economic losses to Maryland's commercial and sport fisheries, hunting, and wildlife watching industries is about $2.8 million per year, but that could balloon to $132.6 million per year in 50 years. Additional environmental and social losses were estimated to currently be at $800,000 per year, but that could also balloon to $37 million per year in 50 years.

Initial programs to reduce nutria numbers were similar to methods employed in Louisiana. The programs involved trying to encourage human consumption of nutria and using a bounty program whereby people were paid $1.50 for each nutria tail (Bounds and Mollett, 2000). Neither of those programs succeeded in reducing the growing nutria population in Maryland.

In 1994, the Maryland Department of Natural Resources convened a nutria summit to address the problems caused by nutria. Dr. M. Gosling, the scientist who spearheaded the successful United Kingdom nutria eradication effort in the 1980s, was brought in to consult and advise the natural resource management agencies. In 1997, a partnership of federal, state, and private natural resource organizations was formed to create a management plan to reduce or eliminate nutria on the Maryland Eastern Shore (Bounds and

Carowan, 2000; Kendrot, 2004). A five year two-phased pilot project was developed, and funding was obtained to initiate the "Maryland Nutria Project" in 2000. The first two-year phase of this pilot project focused on research to describe the health, reproductive characteristics, behavior, and population size of nutria at 9 study sites within the federally-managed Blackwater National Wildlife Refuge (BNWR), state-owned Fishing Bay Wildlife Management Area (FBWMA), and privately held Tudor Farms, Inc. (TF). Led by principle investigators from the University of Maryland Eastern Shore Cooperative Fish and Wildlife Research Unit, graduate students and a staff of 12 technicians conducted mark-recapture population estimates, necropsies, and radio telemetry studies to describe nutria biology in the Chesapeake Bay.

Phase 2 of the pilot project was implemented in 2002 by the US Department of Agriculture's Wildlife Services (WS) program through an interagency agreement with the US Fish and Wildlife Service. WS initially tested two removal strategies, saturation versus perimeter trapping, on the 9 study sites utilized in the first phase of the pilot project. WS quickly determined that testing eradication strategies on relatively small (600 acre) study areas was confounded by immigration from neighboring populations, and that perimeter trapping would not put all animals at risk of capture. Accordingly, the phase 2 study site was expanded to include all of BNWR, FBWMA, TF and private wetlands among and between these properties.

Between 2003 and 2006, 15 wildlife specialists with WS applied a systematic trapping campaign across nearly 100,000 acres in southern Dorchester County, Maryland, removing 10,000 nutria in the process. Continual population monitoring in previously trapped areas indicated that nutria densities were driven to near-zero densities and could be maintained by early detection and removal of new invaders. Marsh damage assessments conducted by the US Geological Survey's Patuxent Wildlife Research Center demonstrated the recovery of marsh grasses in previously damaged areas (M. Haramis, USDI Geological Survey, unpubl. data). At this point, project management decided that landscape-level eradication was achievable and worthwhile. The project scope was expanded to include all of the Delmarva Peninsula and renamed the Chesapeake Bay Nutria Eradication Project (CBNEP).

Using an adaptive management process, the CBNEP team has developed a suite of detection and removal techniques that have been applied over the course of a eradication campaign comprised of five phases:

- The *Survey* phase utilized various detection methods to delimit the distribution of nutria within a watershed or collection of watersheds.
- The *Knock-Down* phase involved the application of systematic trapping to reduce nutria populations to near-zero densities within management units.
- During the *Mop-Up* phase staff focused on the early detection and rapid removal of aggregations of nutria that form within previously trapped areas when new invaders or individuals that avoided trapping coalesce.
- During the *Verification* phase staff repeatedly applied detection methods. Failure to detect nutria despite repeated and ongoing efforts indicated that eradication had been achieved.
- Continual monitoring at a lower intensity during the *Surveillance* phase was conducted to ensure that eradication is maintained.

While these phases were generally followed sequentially, phases may be skipped or revisited depending on the detection of nutria.

No single method of removal or detection is 100% effective and in order to assure that all nutria are put at risk, CBNEP staff relied on a diverse suite of detection and removal tools and techniques. Detection methods and devices included:

- Shoreline surveys conducted by staff traveling by boat or kayak at slow speeds along waterways looking for tracks, scat, and other sign of nutria.
- Ground surveys by foot conducted in areas not accessible by boat.
- Detector dogs used to detect nutria by scent in conjunction with visual sign searches by boat or on foot.
- Detection Platforms are standardized devices comprised of a two foot square plywood base bonded to Ethafoam® for flotation. A wooden rim on the top surface of the platform prevents natural vegetation or straw bedding and any nutria sign (scat) from washing or blowing off the platform. Arrays of platforms were placed along navigable waterways and were routinely inspected for sign of use (scat, muddy tracks, hair samples, etc.). Platforms were also be used as a removal technique by applying a trap once sign has been detected.
- Judas nutria involved the use of sterilized and radio-tagged animals to locate colonies of free ranging nutria.

Removal methods included:

- Body gripping/instant kill traps set in trails, haul-outs, on platforms, and on floating trap stabilizers.
- Foothold traps set on submersion cables that quickly drown captured nutria set along waterways on false beds, platforms, and haul-outs.
- Cage-traps and snares were sometimes used to capture nutria alive for research purposes or in areas where landowners were concerned about use of kill traps around hunting dogs or pets.
- Shooting was an effective means of hunting nutria, particularly in winter months when ice aids mobility and snow cover facilitates tracking.
- Detector dogs were highly effective at finding and removing nutria at low densities.

Detection surveys were replicated numerous times throughout the different seasons in order to reduce the risk of failing to detect nutria when they were present. Similarly, not all nutria were vulnerable to being captured in a single device or set type, therefore, integrating multiple methods insured that all nutria were eventually put at risk of capture.

The key to achieving eradication with these traditional harvest methods was the systematic and progressive manner in which intense trapping pressure was applied and sustained over the long-term. The CBNEP used Geographic Information Systems (GIS) to prioritize staff deployment and manage data, and Global Positioning System (GPS) navigation devices to track staff movements and collect positional data on sign and captures. Using salaried wildlife specialists, prolonged trapping pressure was applied long after commercial trappers getting paid a bounty would abandon an area for more profitable capture rates.

Since expanding its focus to the entire Delmarva Peninsula, by October 2011 the CBNEP had reduced nutria to near-zero densities across 150,000 acres of coastal wetlands along the Chesapeake Bay and its tributaries in 5 counties on Maryland's Eastern Shore: Talbot, Caroline, Dorchester, Wicomico, and Somerset. In October of 2011, staff initiated surveys to delimit nutria populations throughout the rest of the Delmarva Peninsula, detecting previously unknown populations in the Wicomico River. The CBNEP has set a goal of eradicating nutria from the entire Delmarva Peninsula by the end of 2015.

The benefits of nutria removal efforts in Delmarva Peninsula are already being observed. Marsh vegetation has improved dramatically in many areas with large increases in vegetation cover (Figure 5).

Figure 5. Marsh vegetation recovery in the Blackwater National Wildlife Refuge in Maryland after nutria removal. Nutria damaged area (top) and the same area after nutria removal (bottom).

Northwestern United States: Oregon and Washington. Nutria were introduced to Oregon and Washington in the 1930s and into the 1940s for fur farming (Larrison, 1943; Willner, 1982). Nutria were first brought to the Northwest in expectation that nutria farming would become a lucrative endeavor (Guenther, 1950; Kuhn and Peloquin, 1974; Larrison, 1976). However, inflated breeding stock prices, poor reproduction, large farming expenses, and little economic return for nutria pelts (~$1.00 per pelt during the 1950s) resulted in the collapse of an industry whose boom was short-lived (Evans, 1970; Kuhn and Peloquin, 1974; Willner, 1982; Kinler et al., 1987).

More than 600 nutria farms existed in Oregon from the 1930s to the 1950s (Kuhn and Peloquin, 1974), and a number of farms existed in Washington at this time (Larrison, 1943; Guenther, 1950). Flooding and storms damaged holding structures and allowed some nutria to escape from fur farms, however, farmers often released their stock when farming became uneconomical. By the 1940s, feral nutria had been captured by trappers on both sides of the Cascade Mountains in Oregon and Washington, but most nutria were found in the Puget Sound area, the Willamette Valley, along coastal Oregon rivers, and along the Columbia River (Larrison, 1943; Ingles, 1965; Mace, 1970; Kuhn and Peloquin, 1974; Johnson and Cassidy, 1997). Only the Yakima River drainage in south-central Washington supported substantial numbers east of the Cascade Mountains until consecutive severe winters in the late 1970s greatly diminished this population (G. Brady, Washington Department of Fish and Wildlife, pers. comm.). As early as 1943, Larrison (1943) suggested that the nutria in the northwestern states should be studied so that control measures could be implemented before their range expanded. Unfortunately, little study of the growing nutria populations occurred. Indeed, even to the present day, the need for more research on the nutria in the northwestern states is being advocated (Sheffels and Sytsma, 2007).

As the feral nutria populations expanded in Oregon and Washington, nutria were trapped mostly by accidental catch until the 1970s (Sheffels and Sytsma, 2007). Then a major increase in pelt prices in the late 1970s and early 1980s corresponded with large increases in the annual trapping take. Trapping in Oregon peaked in the 1977-78 trapping year when 16,272 nutria were taken (Sheffels and Sytsma, 2007). However, pelt prices decreased and subsequently so did the annual nutria take. This trend was seen in other states, such as Louisiana, as well (Jordan and Mouton, 2010). The records indicate fluctuating harvest levels of nutria, which may reflect fluctuating pelt prices (Verts and Carraway, 1998) rather than fluctuating population densities. Nutria harvest data also indicate a relatively stable population geographically, in that

nutria are consistently captured in the same counties (i.e., nutria do not appear to be spreading to previously unoccupied counties in appreciable numbers).

Short-term population stability, however, does not mean that all habitats suitable for nutria have been colonized or that a range expansion will not occur in the future. For example, Davison and Bohannon (2005) reported a small nutria population in Skagit County, Washington, which is relatively close to the Canadian border. An effort began immediately to remove the animals with the use of traps. Monitoring efforts continue, but no nutria sightings have been confirmed in Skagit County in several years (J. Dayton, USDA Wildlife Services, pers. comm.). In Oregon, anecdotal information suggests populations are expanding throughout the western side of the state, and nutria sightings have been confirmed near the southern border (Sheffels and Sytsma, 2007). A regional nutria habitat suitability model is being developed to identify areas for potential future range expansion in both Oregon and Washington (Carter et al., in prep.).

Initially, the nutria was listed as an unclassified wildlife species according to both Oregon and Washington administrative rules. More recently, it is classified as a prohibited non-native species in both states (Sheffels and Sytsma, 2007), and nutria can be harvested in unlimited numbers at any time of the year. All body-gripping traps (e.g., snares) are illegal in Washington, but no such restriction exists in Oregon. The classification of nutria as a prohibited species requires that all trapped animals be destroyed (i.e., are not to be released back to the wild) to reduce negative ecological and economic impacts caused by the species.

Nutria feed on a variety of plant species in the Pacific Northwest. Wentz (1971) found that broadleaf arrowhead (*Saggittaria latifolia*) and smartweed (*Polygonum* spp.) were selected by nutria in the Willamette Valley, Oregon, and he concluded these species may be locally reduced or extirpated by foraging nutria. Wentz observed nutria feeding on 40 different species of plants, and 15 species accounted for over 80% of the foraging observations. Wentz (1971) also noted that nutria densities varied with water level. Densities were lower (0.26 nutria/acre) during winter, but were much more clustered (56 nutria/acre) in summer when many seasonal ponds and streams were dried up.

Impacts to native vegetation were studied more recently by Meyer (2006) in coastal habitats of Oregon. He used paired exclosures and found that nutria herbivory on native vegetation was considerable, but varied depending on plant species type and disturbance history (Meyer and Beatty, 2006). Nutria foraged more heavily on herbaceous dicots (forbs) compared to monocots (grasses), resulting in lower herbaceous above ground biomass. Interestingly,

below ground biomass did not vary inside and outside the exclosures, which is very different from what was reported in Maryland (Willner et al., 1979). Plant diversity also did not vary inside and outside the exclosures, but the authors noted that the study was only conducted over a 2-year period, hence changes in diversity may not have had time to manifest themselves. Meyer (2006) did not find a significant difference in herbivory in plots that previously had all above ground plant biomass removed ("harvested plots") versus plots that did not have biomass removed, but the unharvested plots had somewhat higher amounts of above ground biomass. Overall, the measured impacts on Oregon vegetation were not as severe as those reported in Maryland and Louisiana. Meyer (2006) also documented considerable erosion of banks as a result of nutria burrowing into banks to make dens. He noted that this could result in deteriorated habitat for native fish species.

Nutria herbivory can also be very destructive to regional wetland and riparian habitat restoration projects. Herbivory at a single restoration project site resulting in damages totaling $400,000 has been documented (T. Esary, City of Vancouver, pers. comm). Sheffels and Sytsma (2009) studied the impact of nutria on a wetland vegetation replanting project in the Willamette Valley, Oregon, and the use of plastic mesh seedling protection tubes to mitigate herbivory damage. Black cottonwood (*Populus balsamifera*), red osier dogwood (*Cornus sericea*), and willow (*Salix* spp.) live stakes were installed and monitored over a 14-week period. Unprotected plantings only had a 12% survival rate over the monitoring period, while live stakes protected by the plastic tubing demonstrated a 100% survival rate. Nutria displayed a preference for black cottonwood over both dogwood and willow, as nearly 90% of the unprotected cottonwood plantings were removed within 10 days. While the protection tubing did eliminate nutria herbivory over the 14-week period, Sheffels and Sytsma (2009) noted that this damage mitigation method may not be as successful over a longer period. In contrast, a similar study in Louisiana reported that plastic mesh tubing was completely ineffective for mitigating herbivory damage, even in the short-term (Conner and Toliver, 1987).

Nutria also have the potential to impact native fauna both directly and indirectly. Apparent declines in muskrat numbers have been observed in areas where nutria are abundant on the Finley National Wildlife Refuge in western Oregon (H. Brunkal, U.S. Fish and Wildlife Service, pers. comm.). Alteration of the vegetative community would be expected to have a significant influence on native fauna, especially sensitive amphibians and species that have niches similar to the nutria (e.g., muskrat, some waterfowl). Unfortunately, little

information is available on the direct or indirect impacts of nutria on other fauna in the Pacific Northwest.

Nutria activities also result in direct and indirect impacts to humans, particularly in developed areas. The largest category of damage caused by nutria in the northwestern states involves burrowing and associated erosion (Sheffels and Sytsma, 2007), compared to extensive marsh damage in Maryland and Louisiana. In addition to erosion in natural systems, nutria burrowing results in substantial damage to private property, roads, and earthen water control structures (e.g. dikes, levees, embankments). This can lead to dangerous situations, with several reports of heavy machinery rolling over due to cave-ins of weakened banks (G. Oman, Wahkiakum County Diking District, pers. comm). Economic impacts can also be sizable, even for private citizens. For example, homeowners living near stream or wetland systems can face costs of thousands of dollars to repair nutria erosion damage (J. Stevenson, USDA Wildlife Services, pers. comm.)

Herbivory damage to a variety of agricultural crops also occurs in both Oregon and Washington. Larrison (1943) warned of the potential of increased damage to vegetable production in the Puget Sound area as early as the 1940s. Kuhn and Peloquin (1974) reported historic nutria damage to agricultural crops in the Willamette Valley and estimated losses of thousands of dollars per year. The crop damage was common to severe by the 1960s with damage to seed, grain, forage, hay, and trees (Kuhn and Peloquin, 1974). Damage to regional agricultural crops such as alfalfa, wheat, corn, peas, and sugar beets is still common today, but comprehensive damage estimates are not available. In contrast, state agencies in California took action early on to prevent the spread of nutria, eliminated most populations, and passed protective regulations on the farming of nutria. As a result, nutria did not become an agricultural pest in California (Schitoskey et al., 1972).

The widespread presence of nutria in suburban areas in the northwestern states creates additional issues (Sheffels and Sytsma, 2007). For example, people feeding nutria in public parks is a common occurrence (Figure 6). This phenomenon can result in high density nutria populations at these locations, increasing the risk of disease transmission. Nutria are known to be reservoirs for a variety of wildlife diseases, some of which are potentially transmissible to people, pets, and livestock (Howerth et al., 1994). Additionally, the potentially aggressive behavior of nutria poses a hazard to children and pets that approach them too closely (J. Tabor, Washington Department of Fish and Wildlife, pers. comm.) (Figure 7). Finally, private property damage issues are widespread. In addition to the erosion damage already discussed, private

citizens often submit complaints of damage to gardens and lawns resulting from nutria feeding (J. Stevenson, USDA Wildlife Services, pers. comm.).

Figure 6. Managing nutria in urban/suburban areas can be particularly problematic. Here, people are feeding carrots to nutria along an urban wetland trail in Gresham, Oregon.

Figure 7. Close encounters with feral nutria can result in bites and disease transfer.

Personnel with the USDA Wildlife Services and state wildlife officers respond to nutria damage complaints. Although a number of damage prevention and control methods exist for nutria, commercial trapping appears to be the most common method used in Oregon and Washington. Some trappers have benefited from the introduction of nutria, although the monetary benefits now appear limited as nutria pelts are no longer highly valued for fur (Verts and Carraway, 1998). Low pelt prices offer little incentive to most trappers and consequently, commercial trapping may be limited as a management tool for nutria populations. Conversely, control of pest nutria can be a source of income for some trappers and pest control professionals. The development of new trapping methods with potentially higher efficiency, such as multiple capture traps (Witmer et al., 2008), are currently being researched (Sheffels et al., in prep.).

Unlike the coordinated control programs in Louisiana and Maryland, no organized nutria control program exists in the Pacific Northwest. Trapping and localized control efforts have been used to manage nutria populations since they were first introduced, and these techniques will likely continue to provide for nutria management in the near future. Trapping records indicate a relatively stable nutria population in the Pacific Northwest. However, nutria breed throughout the year in the northwestern states (Kuhn and Peloquin, 1974; Peloquin, 1969), and this prolific reproductive capability suggests rapid population growth is possible, especially if the current practice of localized nutria control and management continues.

Until new information indicates that regional nutria impacts are particularly severe to certain species, ecological communities, or geographic areas, it is unlikely that current management methods will be greatly altered or replaced. Lobbying efforts to ban trapping or outcries for nutria eradication could alter the status quo, but these scenarios do not appear to be immediate issues in Oregon or Washington. With the exception of research by Peloquin (1969) on growth and reproduction, Wentz (1971) on nutria density and impacts to marsh vegetation, Sheffels and Sytsma (2009) on herbivory damage mitigation, and Sheffels et al. (in prep) on alternative trapping methods, little study of the nutria has been conducted in the Pacific Northwest. Future research should focus on how the nutria's alteration of aquatic environments and its physical presence (i.e., potential competition and disease transmission) could impact sensitive fauna and vegetative communities. This research may also prompt additional work on alternative management techniques for nutria, particularly in suburban areas where current management options are limited.

Nutria Management and Research Needs

Management plans to control nutria populations and their damage typically involve population reduction or eradication (Schitoskey et al., 1972; Gosling and Baker, 1989; Carter and Leonard, 2002). In the past, commercial trapping may have kept nutria populations at lower densities, especially when fur prices were high. However, with the decline in fur prices and reduced trapping effort, other methods to reduce populations and damage must be implemented. The tools used to accomplish reduction or eradication of nutria need to be assessed based on management objectives and approaches. The tools and methods of wildlife management vary by state, and even county, so it is important to make sure that federal, state, and county laws and regulations are being followed.

An analysis of methods to reduce the nutria population and marsh damage in Louisiana was conducted by Genesis Laboratories, Inc., and it serves as a good basis for establishing a management program (Genesis Laboratories, Inc., 2002; Mach, 2002). The potential methods that they identified in declining order of effectiveness were:

- Incentive payment plan;
- Chemical control;
- Incentive-bonus program;
- Trapping;
- Hunting;
- Induced infertility, and;
- Chemical repellents.

They noted that the last two methods are not available for nutria control at this time. The only mammalian infertility control material registered for use in the United States is GonaCon™, but it is only for use as an injectable drug for white-tailed deer (Gionfriddo et al., 2009). No nutria repellents are registered, and no effective repellent products have even been identified through research (LeBlanc, 1994). The incentive payment program, the number one recommendation of Genesis Laboratories, Inc., is the approach that the LDWF implemented as described in the Louisiana case study previously covered.

Rodent management often involves the use of several methods in an Integrated Pest Management (IPM) approach to maximize effectiveness and to minimize hazards to non-target animals (Witmer, 2007). Some aspects of

nutria management options are considered below. Importantly, we discuss recent research and some research needs. Research needs that have been identified include improvement of nutria management and especially monitoring techniques, lures and attractants, toxicants, and multiple capture systems (Bounds et al., 2003; Sheffels and Sytsma, 2007). Additionally, landscape-level population and management modeling may also provide useful techniques to future management (Carter et al., 1999). Finally, we hope that more benefit-cost analyses (e.g., Panzacchi et al., 2007) will be conducted to assure an economic benefit to nutria management or eradication programs.

Monitoring Techniques. Detecting and reducing or eliminating low-density populations of nutria is a major challenge in the effort to completely remove nutria from an area. Low population densities occur when an invasive species is first introduced into an area and again after management efforts to reduce or eliminate the species are implemented. The investment of resources and effort by resource managers can be negated by residual nutria that go undetected and are left to quickly repopulate an area, so methods to detect the few remaining individuals are important. For example, Wildlife Services' use of Labrador retrievers at Blackwater NWR has facilitated their efforts to remove any remaining nutria that personnel may have missed (Kendrot, 2004). Retrievers are effective at detecting nutria on air currents both in open water and mud situations. With the help of retrievers, personnel can remove individual nutria from an area immediately rather than making repeated visits to the site when using traps.

Adequate marking and monitoring methods are also essential for the study of free-ranging nutria. Fichet-Calvet (1999) found that rhodamine B fluorescence remained in nutria guard hairs for at least 255 days, hence could be useful in various nutria population, food habits, and habitat use studies. Radio telemetry has commonly been used in nutria studies, but various problems result from using this method of marking and locating individuals such as radio-transmitter failure or removal and possibly increased predation risk (Nolfo and Hammond, 2006; Nolfo-Clements, 2009). Nolfo and Hammond (2006) found that implanted radio-transmitters alleviated some of these problems. Similarly, Meyer (2006) found that injected passive integrative transponders (PIT tags) were an effective nutria marking method and did not result in the problems found with ear tags and radio-transmitters. Haramis and White (2011) developed a beaded collar to which radio-transmitters could be attached. These devices were lighter and caused less friction than traditional radio-transmitter collars. Similarly, Merino et al. (2007) developed a tail-mounted radio-transmitter for nutria which avoided

some of the problems that neck collars cause. Finckbeiner (2005) developed a method to recognize individual nutria from their whisker pattern. Finally, Callahan et al. (2005) identified a suite of microsatellite DNA markers that can be used to study population dynamics, migration, and breeding structure in nutria populations.

Lures/Attractants. Lures and attractants are useful in nutria control for attracting nutria to sites where a treatment is presented (e.g., trap, rodenticide bait station, monitoring device). Attractants can increase the number of nutria visiting bait stations and reduce time required for bait stations to be operational, thereby reducing non-target exposure. Most rodent species have a keen sense of smell and respond to various odors (Mason et al., 1994). When presented with visual, auditory, and odor cues, nutria responded best to odors; thus olfactory cues appear to have the greatest potential for developing future attractants (Nolte et al., 2004). In other olfactory trials, nutria were most attracted to synthetic semiochemicals such as fur extract from female nutria and nutria anal gland secretions (Finckbeiner, 2005; Lee et al., 2007; Jojola et al., 2009). Additionally, nutria are more attracted to fertilized marsh plants when offered with non-fertilized marsh plants (Witmer et al., 2008; Jojola et al., 2009). Conversely, while nutria emit audio calls, recorded calls tended to be avoided and nutria are indifferent toward live conspecifics as cues (Nolte et al., 2004). The assessment of other potential olfactory attractants for nutria should continue to increase the effectiveness of management techniques.

Trapping. As previously discussed, trapping is an important nutria management tool with cage, leg-hold, and kill traps all being used (LeBlanc, 1994). However, Chapman et al. (1978) noted that leg-hold traps caused more injuries and deaths to nutria than cage traps. Some researchers have found that the placement of traps on floating platforms reduces non-target animal captures and increases trapping success (Baker and Clarke, 1988; Welch, 2005). Another study found baited rafts to be less effective when placed in coastal marsh, but the researchers noted that nutria had access to other food sources available in late spring when the study took place (Nolte et al., 2004). They suggested employing baited rafts during the winter when native forage is less abundant. In Germany, Meyer (2006) was able to capture adequate numbers of nutria for field studies using a dip net. However, that was in an urban setting where the nutria were acclimated to the presence of humans. Multiple-capture traps (Figure 8) would enable several nutria to be captured within a single trap, thereby reducing the effort of maintaining numerous traps and checking them frequently. Traps with one-way doors are ideal for multiple-capture systems in that captured live nutria may serve as a lure for

other nutria in the area. Witmer et al. (2008) developed and tested a nutria multiple-capture live trap. The traps were effective in catching nutria when baited with fertilized marsh plants or food items such as corn, carrots, and grains. Researchers or trappers can visit these traps periodically (as per state regulations) to mark and release nutria, to remove and translocate the nutria (where regulations allow), or to euthanize the nutria. Additional research on the efficacy of this multiple-capture trap design is being conducted (Sheffels et al., in prep).

Toxicants. Zinc phosphide is the only toxicant currently registered for controlling nutria in the United States (LeBlanc, 1994), but other rodenticides have the potential to be effective control materials for nutria (Genesis Laboratories, Inc., 2002; Mach, 2002). Schitoskey et al. (1972) recommended toxicants, such as zinc phosphide, for large-scale nutria control. Placing zinc phosphide-treated bait on rafts has been an effective method to reduce nutria populations on canals and other open waterways and to reduce exposure to non-target animals to the toxic baits (LeBlanc, 1994). There is a growing concern in the United States and several other countries about primary (consumption of the toxic bait) and secondary (consumption of poisoned nutria) exposure of non-target animals to rodenticides and especially anticoagulant rodenticides. Evans and Ward (1967) found that dogs and mink (*Mustela vison*) could be poisoned by feeding them nutria that had been poisoned with anticoagulants and recommended that these compounds not be used to control nutria in coastal areas of the United States. Conversely, Witmer et al. (2010) determined that the risk to alligators from consuming poisoned nutria was low.

Figure 8. Nutria within a multiple-capture live trap in Louisiana.

Conclusion

Our review demonstrates the significant impact that a large, invasive, aquatic herbivore can have on marsh ecosystems and other valuable resources. Introduced nutria are a challenge to control and even more difficult to eradicate from a sizable area. However, with an effective strategy and sufficient resources and effort, they can be removed from large areas. Alternatively, intensive management of populations can maintain nutria densities at levels whereby damage to marshes and other resources can be kept at environmentally and economically acceptable levels. Improving the tools available to managers would enhance the effectiveness and efficiency of nutria control. For example, Labrador retrievers are more commonly being used to detect nutria at low densities. Effective attractants will most likely be biologically-based or food-based olfactory cues and would serve to enhance other means of control such as single-animal and multiple-capture traps and rodenticide baits. Zinc phosphide is currently the only registered toxicant for nutria, and research has been conducted to improve its effectiveness while reducing potential hazards. Other toxicants could be developed and tested on nutria, along with different types of delivery systems. Substantial progress has been made on methods to mark, monitor, and identify individual nutria for field studies and control efforts. We now know that marsh ecosystems can recover after nutria population reduction or elimination. Hopefully, sufficient resources will be made available and effort put forth to accomplish the task of population reduction or elimination in the United States and other countries where nutria have been introduced.

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