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A HISTORY OF MUSKRAT PROBLEMS IN NORTHEASTERN CALIFORNIA

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ABSTRACT: Northeastern California contains several extensive areas of natural and man-made wetland and marsh type habitats. These areas were void of muskrat (*Ondatra zibethicus*) until the early 1930s when deliberate introductions were made. Once a valuable renewable resource before the sharp decline in pelt prices and strict regulations on trapping, the muskrat has become a nuisance pest species for resource managers. Muskrats have caused extensive damage to water delivery systems, levees, dikes, stream and river banks. Other damage includes impacts on pasture, crops, livestock, property, fencing, fisheries, endangered species, and human health and safety. This paper will look at the types of damage caused by the muskrat and some of the management approaches being taken to reduce or alleviate this damage.

KEY WORDS: damage, introductions, management, muskrat, *Ondatra zibethicus*, pest, wetland

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INTRODUCTION

The muskrat (*Ondatra* spp.) inhabits fresh and salt water marshes, ponds, lakes and rivers in North America and Europe. Muskrats are the most valuable fur bearing animal in the United States with the harvest being six or seven times that of any other fur bearing species. During the 1982-83 trapping season when fur prices were peaking, more than seven million muskrats were harvested in North America for a total value of \$28 million (Boutin 1987). Northeastern California also had an active muskrat trade as fur trapper take totaled tens of thousands of muskrats annually. But with the decline of fur prices and the passage of recent laws restricting the type of equipment which can be used to capture muskrats, many private trappers have quit trapping. Several resource agencies and private land managers are struggling to find ways to manage this dynamic rodent.

HISTORY

In California the muskrat is native only to the Colorado River and Great Basin Region (Grinnell et al. 1937). Scattered populations of muskrats in the Great Basin Region were found from Northern Mono County north to Eagle Lake in Central Lassen County. Muskrats were not present in the Sacramento and San Joaquin valleys, the Modoc Plateau, or the Pit River Drainage in Northeastern California (Newberry 1857; Storer 1937). The muskrat has been introduced into many areas where it did not occur naturally. Some of these introductions have been deliberate; others have been accidental-escapes from fur farms. Storer (1937) documents several known introductions in California and on several islands off the coast of British Columbia. Muskrats were introduced into the Fall River drainage in 1930 from the Mount Shasta Fur Farm. In May 1929, from growing concerns from impacts by two introduced muskrat populations in Imperial Valley (Dixon 1922) and Kern County, the Department of Fish and Game, at the suggestion of State Department of Agriculture, gave notice that no permits would be granted for muskrat farming west of the Cascade-Sierra Nevada Mountains (Storer 1937). This was intended to stop the introduction and spread of

muskrats into California's central valley region. However, in February 1930, a permit was issued to Mount Shasta Fur Farm after declaring that a secure fence would enclose the farm and prevent escapes. Mount Shasta Fur Farms established a muskrat farm that year about 6.4 km (4 miles) north of McArthur on Big Lake. Muskrat breeding stock from Ohio, Colorado, and North Dakota were bred in pens, then released the following year into fenced enclosures. By 1932 almost 600 muskrats had been released into large fenced areas (Storer 1937). Reports of escapes started in 1932 and possibly even in 1931. In 1933 the State Department of Agriculture hired five trappers during May and June and took 1,818 muskrats before funding ended. Shasta County and Pacific Gas and Electric (PG&E) power company employees trapped another 1,148 muskrats that fall, and 496 were within the fenced area (Storer 1937). From 1934 to 1935 another 10,088 muskrats were reported trapped within the Fall River Valley area. By 1938, muskrats were found throughout the Fall River, Pit River, and lower Hat Creek drainage (Storer 1938; USFWS 1997). Muskrats were also released into the Tulelake and Lower Klamath drainage to create a harvestable resource. The muskrat has expanded its range in California over the last 100 years as a result of fur ranching (Seymour 1954). Muskrats that escaped from fur ranching operations in the Sacramento River Drainage found an excellent habitat in natural marshes and in the increasing number of irrigation canals and drains in California's Central Valley.

GENERAL BIOLOGY

Muskrats can live almost any place where water and food are available. This includes streams, ponds, lakes, marshes, canals, roadside ditches, swamps, beaver ponds, mine pits, and other wetland areas. Muskrats construct two types of dens. They may be small huts made of vegetation primarily rushes and cattails, or bank dens constructed from burrowing activities in river and/or stream banks. The greatest damage that muskrats cause is from burrowing. They damage pond levees, flood protection levees, and river and lake shorelines.

Musk rats are primarily herbivores that will eat almost any aquatic vegetation. Some of the preferred natural foods include cattail, pickerelweed, bulrush, smartweed, duck potato, horsetail, water lily, sedges, young willow regeneration, and other aquatics. Crops that are occasionally damaged include corn, soybeans, wheat, oats, grain sorghum, and sugarcane (Miller 1994). Although the muskrat is primarily herbivorous, in some localities the muskrats may feed on crayfish, crabs, mussels, snails, minnows, and fish (Miller 1994).

Musk rats have a long, laterally compressed tail and webbed hind feet. Adults average 1 to 1.4 kg (2.2 to 3 pounds) in weight and have a total length of 40 to 65 cm (16 to 25 inches) (Boutin 1987). Their thick waterproof fur can vary in color from light brown to black. Mating takes place during the latter part of March. The gestation period is between 28 to 30 days. Females are capable of breeding immediately after giving birth (Wilson 1955). In northern areas, two litters, and occasionally a third, are produced a year. Litters may contain as many as 15 young, but the average is between four and eight young. Females can breed as early as six to eight weeks of age and do so in the southern United States where aquatic vegetation is continuously available (Hall and Kelson 1959). This capability affords the potential for a prolific production of young. Musk rats in the northern regions won't breed until the spring following their birth.

IMPACTS

Negative economic attributes of muskrats include burrowing and damage to dikes, ditches, ponds, and levees, and crop losses. Musk rats may cause substantial damage to natural as well as man-made habitats. If water levels remain constant, muskrat burrows are hard to detect because entrances are below the normal water line. Lowery (1974) found that when food is abundant muskrat populations increase rapidly. When all available vegetation is eaten, muskrats may dig down into the peaty marsh floor as deep as 50 cm (20 inches) to devour roots. As roots that bind marsh soils together are removed, the earth disintegrates into loose muck with decaying remains of plants floating in the ooze. Lynch et al. (1947) found that marsh damage was inevitable when areas heavily populated by muskrats were under trapped.

FALL RIVER VALLEY

The Fall River valley watershed consists of three river drainages (Pit, Tule, and Fall rivers) and several lakes (Big, Eastman, Fall River lakes) and Horr Pond. Land adjacent to these waterways is in private ownership. Some 20 km (12 miles) of levees were built in the early 1900s to contain the Tule rivers and Big Lake. In 1922, PG&E completed their Pit 1 hydroelectric project which diverted water from Fall River through the Pit 1 powerhouse. Fall River is approximately 27 km (17 miles) long with a low gradient. It slowly meanders through farms and ranches. Fall River has been long known and managed as one of California's Blue Ribbon trout streams.

Impacts on the Fishery

The effects of muskrat activity on the fishery of Fall River can be manifested in several ways. Their

burrowing habits can be detrimental to the stability of stream banks and may not be readily apparent until serious damage has occurred. Burrows usually extend several meters into the bank and are the source of most muskrat caused damage in the U.S. (Miller 1994). Over time, banks perforated by many muskrat dens tend to collapse, destroying overhanging bank cover and causing sediment to enter the stream. Musk rats also dig feeder tunnels in nearby pastures and yard areas. Feeding tunnels are dug just under the sod layer for root feeding and can extend up to 25 m (80 feet) in length. These tunnels are started along the banks just below the water line. All material removed during digging activities is pushed into the water. In this way muskrat activity can destroy a quality trout habitat through direct loss of cover and an increase in sedimentation.

Another important aspect of burrowing is the cumulative effect on overall stream channel morphology. Bank collapse can result in a widening and shallowing of the stream. This can cause increased water temperature and a reduction in available trout habitat. Increased sedimentation rates limit deep water cover for larger trout. These effects also decrease shoreline cover and rearing habitat for juvenile trout. This process, while being detrimental to trout, causes habitat changes that favor non-game fish species. These effects can contribute to an overall decline in the Fall River trout fishery.

Musk rat feeding activities on riparian vegetation also have a negative effect on trout populations. A large muskrat population can consume copious quantities of riparian vegetation that leads to further denuding of stream banks. When muskrats become overpopulated, generally an eat-out occurs and the feeding area is ruined for several years (O'Neil 1949). Riparian plants consumed by muskrats are important to trout in several ways. They act to stabilize stream banks with extensive root structures, provide cooling shade to near-shore waters, provide cover for juvenile trout, and act as an energy dissipation element during high flows. Many riparian plant species also provide critical habitat for insects that can be important food sources for trout. Conservation groups have organized willow planting days along damaged areas of the Upper Fall River. Musk rats have negatively effected these efforts by consuming the willow cuttings prior to establishment.

Loss of Fencing

Musk rat burrowing activity has been associated with the undermining of fencing installed to exclude cattle from stream banks. This can be seen in some areas along Fall River. Local landowners, Fall River Resource Conservation District (FRRCD), and the California Department of Fish and Game (CDFG) have made great strides toward preventing cattle from causing stream bank erosion. This effort is a critical component of the management of Fall River as a "Blue Ribbon" wild trout fishery. Musk rat burrowing activity may be undermining this effort. In 1988, a fencing program was started on Fall River to exclude cattle from the river bank. These fences were set back 6 to 10 m (20 to 33 feet) from the water's edge. Musk rats continued to burrow, construct dens, and dig feeder runs under the fences. The banks have degraded to the point that some of the fencing is at

the water's edge and starting to fall into the river. While the problem does not appear severe in some areas, failure to control the muskrat population along the river may result in a less effective cattle exclusion program. Several landowners along the river feel that fencing is a waste of money until something is done to control the muskrat population. This effect will be seen through direct loss of exclusionary fencing, increased cost of fence maintenance, and possibly the loss of landowner cooperation.

Some evidence suggests that not excluding cattle from riparian zones increases the negative impacts of muskrats. The typical stream bank trampling caused by cattle is severely exacerbated by the presence of muskrat burrows. The burrows are easily collapsed by the weight from the cattle and then abandoned. Muskrats quickly begin burrowing new dens. These new burrows are destroyed by cattle, and the cycle repeats. This vicious cycle can lead to the rapid destruction of stream banks. The exclusion of cattle from the riparian zone and the control of muskrats should be complementary activities for continued successful trout management in Fall River.

Damage to Levees

Beginning in 1903, the McArthur family began construction of approximately 20 km (12 miles) of levees to hold Big Lake, Tule River, and Little Tule River in their present configuration (USFWS 1997). These levees helped reclaim 18 square km (7 square miles) of land for farming and pasture. After the completion of the levees, muskrats were introduced into Big Lake around 1930. The muskrats built dens and burrows causing the levee to collapse and erode. In 1940, an annual dredging operation started to rebuild and repair the levees. Eventually all the levees were fenced to keep livestock from breaking down the levee face. Even with annual maintenance several levee blowouts have been reported. A recent levee collapse happened in January 1997 when a levee along Tule River broke. At the time of the break, the water level was about 3 to 4 m (10 to 13 feet) above the ground level opposite the levee. A 200 m (650 feet) long break was quickly washed into the levee. The break flooded south toward McArthur 4.5 km (3 miles). More than 10 square km (4 square miles) of pastureland was flooded. Repairs took several months as rock was hauled in to build a road to the damaged area. After the levee was repaired, the escaped water had to be pumped back into the river. Cost estimates were unavailable.

Hazards to Livestock

Livestock feeding or traveling along the river bank or levees could potentially collapse or destroy areas containing muskrat burrows or dens. Often cattle become injured from stepping into a burrow or den. One rancher reported losing a steer after it fell through a muskrat den and into a 2 m (6.5 foot) pit. The steer was found dead in the pit. Other cattle have been pulled from collapsed muskrat dens with no injuries.

Damage to Pasture

A levee along the north side of the Tule River had a blowout during 1998. The break resulted in the flooding of 160 ha (400 acres) of pastureland. Another levee blowout during 1999 resulted in flooding 80 ha (200

acres) of pasture. As of this date neither levee has been fixed. Both of these pastures have drowned out and must be replanted whenever the levees are repaired.

Another problem muskrats cause to pastures is the loss of irrigation water. Muskrats burrowing in from Fall River may dig feeding runs which extend 25 m (80 feet) out into the pasture. Where these feeding tunnels surface in the pasture, irrigation water flows down them and empties into the river. Dry areas start to occur in the pasture and production is lost. The irrigation water lost in the muskrat burrows carries sediment from the tunnels and causes erosion. This erosion leads to increased sedimentation of waterways.

Bank Depression

Bank depression occurs over substantial time and may not be initially identified. In 1979, a small vacant field was purchased next to upper Fall River. Lack of grazing during the previous years resulted in thick stands of grasses. The new owners soon built a new home on the property. The home faced the river and stood 30 m (100 feet) back from the river's edge. After about five years the owners noticed that the water line was about 3 m (10 feet) closer to their home, however the river's water level remained the same. Within 10 years the waterline had moved another 4 m (13 feet) closer to their home. The next 10 years saw the water line come another 6 m (20 feet) closer to their home. The top layer of soil around the area showed no signs of disturbance. This phenomena was the result of muskrat burrowing activities. The muskrats built feeder tunnels onto the property. As more tunnels were dug and expanded, the sod layer supported and maintained an even surface. As the weight of the sod compressed the remaining soil between the burrows, the ground slowly sank until it was below water level. Over a 20 year period the homeowners lost approximately 13 m (43 feet) of river front property.

Impacts on Endangered Species

In 1988, the Shasta crayfish (*Pacifastacus fortis*), was state and federally listed as an endangered species. The Shasta crayfish is the only surviving species of crayfish native (endemic) to California (USFWS 1997). The U.S. Fish and Wildlife Service recovery plan for the endangered Shasta crayfish states that muskrats are impacting the Shasta crayfish by burrowing, sedimentation and bank collapse. These actions are covering volcanic cobbles and boulders which are essential habitat components. Muskrats also prey directly on the Shasta crayfish, greatly jeopardizing its continued existence.

TULELAKE BASIN

The Tulelake Basin is an area of fertile farmland lying on the California/Oregon border. The area supports many crops including potatoes, sugar beets, mint, grain, and horseradish. To supply water for these crops, miles of irrigation canals were built to carry water to and away from these farming areas. In the early 1930s, muskrats were released into the area to develop a commercial fur resource. The waterways and marshes provided an excellent habitat for the muskrat and they soon occupied the entire basin area.

Tulelake Irrigation District

Damage to Irrigation Structures. The Tulelake irrigation district is in charge of meeting the water needs of the farmers within the Tulelake Basin. To accomplish this, the water district must maintain and repair 400 km (250 miles) of delivery canals and another 500 km (310 miles) of drainage canals. These water systems provide homes for thousands of muskrats each year. The muskrats build their dens and burrows in the banks of the irrigation canals. The banks become perforated and collapse from the weight of equipment or vehicles using the levees. Some tunnels are dug through the levee and the canal starts to leak. One common problem is muskrats burrowing activity around delivery head gates. This is where water is taken from the canal through the levee. The muskrat digs along the diversion pipe or culvert as it runs through the levee. Water soon starts running through the muskrat burrow causing the dirt around the culvert to erode. Soon flooding occurs and the water cannot be shut off at the head gate. The canal must be emptied and the head gate and culvert must be excavated and reset. This causes interruptions and delays in water delivery.

Damage to Crops. If muskrat burrows are extensive enough to collapse a levee or a muskrat tunnel goes undetected where water is being lost from the canal a major blowout can occur. Two recent blowouts along the delivery canal caused major flooding and damaged crops. In 1987, a blowout flooded a potato field and caused \$46,000 in damages. Another blowout in 1990 caused flooding and crop losses to potato, pea, and barley fields. Total damages from the second blowout amounted to \$55,000 (J. Pyle, pers. comm.). These amounts had to be paid by the irrigation district to the farmers because it is the district's responsibility to maintain the levee system. Sometimes muskrats leave the canals to feed in the nearby crops. Most of this damage occurs along the canal banks or irrigation ditches in the first few meters of crop.

Loss of Water. Water in the Tulelake Basin has become a precious commodity. The limited supply of water is wanted for many uses. Water users are constantly battling in court to save their water rights. The water is too valuable to be running down a muskrat hole, but that is what is happening. Thousands of muskrat holes line the canals allowing water to escape into the ground. Some of the water is lost when it travels from the delivery canals through muskrat burrows into the drainage canals. The delivery canals are elevated 1 to 1.5 m (3.5 to 5 feet) higher than the drainage canals.

Flooding of Residences. Part of the town of Tulelake was built in a low-lying area. An elevated delivery canal runs next to the subdivision. Leaks from muskrat burrows have been responsible for flooding yards and streets. Damage to one house was also reported. The area is constantly monitored so any leaks can be fixed before major damage to the subdivision occurs.

Sewage Ponds. Sewage is treated in elevated containment and settling ponds. Muskrat activity was observed at the ponds causing fear of bank degradation. Any break in the containment ponds would put raw sewage into local waterways. The sewer ponds were sprayed and all vegetation along the banks was killed.

The muskrats had no food source at the ponds and migrated back to the canals.

LOWER KLAMATH/TULELAKE NATIONAL WILDLIFE REFUGE

The Lower Klamath/Tulelake National Wildlife Refuge complex encompasses 34,400 ha (86,000 acres) along the California/Oregon border. Although many species of wildlife use the refuge, it is a key location for migratory waterfowl within the Pacific Flyway. The Lower Klamath section consists of 10,000 ha (25,000 acres) of marsh and 8,800 ha (22,000 acres) of seasonally flooded areas. Eighty km (50 miles) of ditches and drains are needed to maintain ideal wetland conditions for waterfowl (J. Hainline, pers. comm.). Muskrat burrowing and denning in the levees and dikes, cause collapses and blowouts. These blowouts can have major impacts on waterfowl, especially during spring months. When waterfowl are nesting, water levels in the flooded areas must remain constant. Any rises in the water level could flood existing nests and drops in the water level could expose nests to predation.

Other problems caused at the refuge by muskrats include collapse of roads from vehicles and heavy equipment driving over muskrat dens. Muskrats burrowing along irrigation structures, head gates and culvert pipes causes washouts and uncontrolled water flow. Most dike collapses occur when water is used to flood the seasonally flooded areas to create more open water. Damaged areas must be rebuilt which slows the flooding process. The refuge is visited by many bird watchers and waterfowl hunters. People using the area have fallen into collapsed muskrat dens and burrows.

JUANITA LAKE

Juanita Lake was built in the 1950s. It lies on Klamath National Forest Land located about 10 miles west of MacDoel, California. This secluded 16 ha (40 acre) lake is a popular recreation spot and a well-kept secret of local residents. To reach the lake muskrats migrated about 8 km (5 miles) up a small stream. The lake freezes over in the winter, forcing the muskrats to migrate back down stream each fall to open water canals and ditches at Meise Lake. During the 1980s the lake's earthen dam became perforated by muskrat burrows. The dam's structural integrity was in question, as leaks started growing. In 1985, the lake was drained and reconstruction of the dam started. The base material was excavated and re-packed to eliminate the muskrat dens and burrows. Large pieces of crushed rock were hauled in to line the lake side of the dam. This excluded the muskrats from the dirt surface and prevented any new burrows from being dug. Work was completed in 1986 and the lake refilled. No further muskrat damage has been reported.

DAMAGE PREVENTION

The muskrat is the most valuable fur animal in North America (Boutin 1987). It leads all other North American wild furbearers in number caught and overall pelt value. Muskrat furs are the most common fur on the market (Deems and Pursley 1978). However, muskrats

may cause severe damage to both natural resources and agriculture. Since economics do not usually allow agricultural pests to go unchecked, many California farmers and irrigation water suppliers try to control their losses, and thus try to control muskrat populations to some extent (Belluonini 1978).

Regulation of the harvest is an important muskrat management measure. Trapping is a feasible way to regulate muskrat numbers (Cook 1952) and the steel leg-hold trap is a very effective tool to capture muskrats. Fifty percent of the muskrat population can be harvested without jeopardizing the population (McCann 1944). Trapping for damage prevention and population control differ from trapping for fur and maximum sustained harvest. Many of the same techniques are used such as traps. However, additional control tools such as exclusion, toxicants, shooting, and lengthened harvest period must be considered when trapping for damage prevention.

METHODS OF CONTROL

The most effective approach to resolving wildlife damage problems is to integrate the use of several methods, either simultaneously or sequentially. Integrated Pest Management (IPM) is the integration and application of practical methods of prevention and control to reduce damage by wildlife while minimizing harmful effects of control measures on humans, other species, and the environment. IPM may incorporate Resource Management, Physical Exclusion, Wildlife Management, or any combination of these, depending on the characteristics of specific damage problems.

In selecting control techniques for specific damage situations, consideration is given to the responsible species and the magnitude, geographic extent, duration and frequency, and likelihood of wildlife damage. Consideration also must be given to the status of target and potential non-target species, local environmental conditions and impacts, social and legal aspects, and relative costs of control options. The cost of control may sometimes be a secondary concern because of the overriding environmental, legal, and animal welfare considerations. These factors are evaluated in formulating control strategies that incorporate the application of one or more techniques.

A variety of control methods and strategies based on applied IPM principles should be used in implementing a muskrat control plan for the Fall River and Tule River drainage. Three general strategies for control of muskrat damage are Resource Management, Physical Exclusion, and Wildlife Management. Each of these approaches is a general strategy or recommendation for addressing wildlife damage situations. Within each approach, there are a number of available specific methods or tactics. Mechanical methods generally are used and recommended in preference to chemical pesticides. No pesticide is used or recommended if it is likely to adversely affect fish, wildlife, food safety, or other components of the natural environment.

Various Federal, State and local laws and regulations govern use of control tools and pesticides. The following muskrat damage control methods will be evaluated in developing a Muskrat Control Plan.

- Resource Management
 - Controlling Water Levels
 - Stream Bank Sloping
- Physical Exclusion
 - Netting (hardware cloth, solid metal, chain link)
 - Rip Rapping
- Wildlife Management
 - Habitat Management
 - Capture Methods
 - Chemical Toxicants

Resource Management

Resource management includes a variety of practices that may be used to reduce muskrat damage. Implementation of these practices is appropriate when the potential for depredation can be reduced without significantly increasing the cost of production or diminishing the resource owner's ability to achieve land management and production goals.

Controlling Water Levels. Changing water levels in the river would work two ways. First, if the water could be drawn down during the winter months 1 m (3 feet) from normal levels, it would expose the muskrat dens and entrances to predators. Decreasing the water level would also force the muskrats to leave the water in most areas to forage, causing further exposure to possible predation. A second benefit of controlling water levels would be to raise the levels during denning, forcing the muskrats to abandon them and disrupt their breeding season. Except when spring rains cause limited flooding, Fall River's water level is maintained within 30 cm (12 inches) of normal flow year around. Muskrat burrows are exposed only during a levee break. Muskrats can depend on non-fluctuating water conditions and a permanent home throughout the year.

The Tulelake Irrigation District uses water level management to help reduce the amount of damage caused by muskrats. Each fall after the irrigation season is over, the delivery canals are emptied and the drainage canals slowly run dry. The muskrats are concentrated into the areas with remaining water where they could be shot or trapped. Many of the muskrats follow the canals back to the Tulelake marsh where they spend the winter. After the canals are refilled in the spring, the muskrats reoccupy and the damage cycle continues. This limits the damage to a seasonal term when the canals are actively transporting water.

Stream Bank Sloping. Areas along the Fall River that have steep banks along the water's edge make excellent places for muskrats to burrow. Muskrats burrow into the banks below the water line and build dens in the bank above the high water mark. It would be impractical to replace all the banks along the river but in the future if any banks or levees need rebuilding then this method could apply. Banks should have a slope of 1 m (3 feet) of run for each 0.33 m (1 foot) of rise. Also the bank or levee should be at least 1 m (3 feet) high and 3 m (10 feet) across at the top (Miller 1987). The water level should not vary more than 0.15 m (6 inches) throughout the year. Some muskrat activity would continue in these sloped banks, however overall muskrat activity would be diminished.

Physical Exclusion

Physical exclusion methods restrict the access of wildlife to resources (in this case riverbanks and head gates). These methods provide a means of appropriate and effective prevention of wildlife damage but are not practical in many situations.

Concrete. Concrete is used to line many irrigation canals and water containment structures as a long term exclusion solution for muskrats and other burrowing rodents. Concrete however is expensive and usually unwanted in natural scenic areas. The concrete would remove bank habitat used by many other wildlife species.

Netting. Netting consists of wire netting, hardware cloth, or chain link fencing along banks to prevent muskrats from burrowing. The netting must be of two inch grid size or less and must be placed from the bottom of the bank and extend up several meters (6 feet) above the high water line. This method has been used along some canal and ditch banks in the Sacramento Valley. In areas where trees and willows are present netting has proven impractical. Also, along steep banks the bottom of the netting is difficult to attach securely to the bank to prevent the muskrats from swimming underneath and gaining access to the bank. Netting is mostly used as a temporary exclusion along canal banks until they can be permanently lined with concrete.

Rip Rapping. Rip rapping consists of using large rock or chunks of concrete to line the face of the bank. The rip rap material starts from the river bed up the bank two to three feet above the high water mark. A layer of material 0.3 to 0.5 m (1 to 1.5 feet) thick should be compacted together which prevents the muskrats from squeezing between the rocks. Although this is an expensive method, it is also a long term cure for muskrat damage problems.

Wildlife Management

Controlling wildlife damage through wildlife management is achieved through the use of a myriad of techniques. The objective of this approach is to alter the behavior or reduce the numbers of the target animal to eliminate or reduce the potential for loss or damage to property.

Habitat Management. Just as habitat management is an integral part of other wildlife management programs, it also plays an important role in wildlife damage control. The type, quality, and quantity of habitat are directly related to the wildlife that is produced. Therefore, habitat can be managed to not produce or attract certain wildlife species. One method of habitat management is to reduce or eliminate preferred aquatic plants in the area. These plants would include cattails, bulrush, horsetail, sedges, young willow regeneration, and others. Removing this vegetation would reduce the carrying capacity for muskrats on the river but could cause more sediment problems and create greater impacts on other species. This method is used at sewer treatment plants and along some irrigation canals where natural vegetation can be eliminated without causing erosion or impacts to other species.

Capture Methods. In November 1998, California voters passed Proposition 4 which further restricted the use of control equipment in the state. Fur trappers could

no longer use the leghold and conibear traps which were by far the most widely used in capturing muskrats. A lesser used tool, the snare was also banned for use by fur-trappers. This left the cage trap as their only capture method. Shooting is not usually preferred if the pelts are to be sold. Depredation trapping was allowed the use of the conibear, snare, and cage trap as long as the hides were not sold or used for commerce.

Several trapping schemes may be employed for muskrats. The whole territory may be encircled and then gradually worked inward, or the area may be divided and trapped on a rotational basis to reduce travel. If traps are concentrated too much, generally greater than one trap per five beds, muskrats may move (Lay 1945).

Leghold Traps. Although the leghold has historically been the most widely used trap for catching muskrats, its use has recently been prohibited in California. The most common leghold traps used for trapping muskrats are the single spring number 1 and 11/2 and the softcatch 11/2. Leghold traps can be set under a wide variety of conditions but can be difficult to keep in operation during rain, snow, or freezing weather. When placed without baits in the travel lanes or feeding areas of target animals, leghold traps are known as "blind sets." More frequently, traps are placed as "baited sets," meaning that they are used with a bait consisting of the animal's preferred food or some other lure, such as musk, to attract the animal. Various tension devices can be used to prevent animals smaller than target animals from springing the trap. Effective trap placement also contributes to trap selectivity; however, non-target animals may still be captured. These traps usually permit the release of non-target animals. Before leghold traps are employed, their limitations must be considered. Injury to target and non-target animals may occur. Weather and the skill of the user will often determine the success or failure of the leghold trap in preventing or stopping wildlife damage.

Quick-Kill Traps. Conibear traps are used mostly in shallow water or underwater to capture muskrat, nutria, and beaver. The conibear consists of a pair of rectangular wire frames that close like scissors when triggered, killing the captured animal with a quick body blow. Conibear traps have the added features of being lightweight and easily set. The number 110 and 120 conibear are the sizes used for muskrat trapping. As with leghold traps, proper placement and use is key to selectivity toward the target species. The conibear trap is widely used by muskrat trappers today.

Cage Traps. A variety of cage traps are used in controlling muskrat damage. A cage trap baited with food and set at a feeding site will capture muskrats, but the mostly commonly used cage trap is the double door colony trap. This trap is long and narrow with a door at each end and placed in muskrat runs both above and below water. This trap can make multiple catches before it needs to be reset. A floating colony trap is a floating platform with a feeding station inside a cage with multiple entry doors.

Snares. Snares made of wire or cable are among the oldest existing control tools. Snares can be effectively used wherever a target animal moves through a restricted lane of travel (i.e., trails through vegetation, or den

entrances). When an animal moves forward into the loop formed by the cable, the noose tightens and the animal is held. Stops can be placed on the loop of the cable so any non-target animal can be released. Snares have not been widely used to capture muskrats.

Shooting. Shooting is used selectively for target species but may be relatively expensive because of the staff hours sometimes required. Nevertheless, shooting is an essential control method. Use of shotguns would reduce risk to people and livestock in the area. Shooting can be more effective at dusk and at night when muskrat activity is the highest.

Chemical Toxicants. Several toxic chemicals have been developed to control wildlife damage and are widely used because of their efficiency. Toxicants are generally not species specific, and their use may be hazardous unless used with care by knowledgeable personnel. The proper placement, size, type of bait, and time of year are keys to selectivity and successful control.

There are three pesticides used for muskrat control. The most widely used is a paraffin bait block which contains grain and one of the anticoagulants diphacinone or chlorophacinone. These baits are placed at feeding stations and have the best acceptance when other food sources are not plentiful. Anticoagulants are normally classified as multiple-dose toxicants. For the materials to be effective, animals must continually feed on the bait for several days. Zinc phosphide is used for controlling muskrats in several states. Zinc phosphide is applied to cubes of carrots, apples, or potatoes and placed on floating bait stations or in bait stations located along the bank where muskrats have easy access. Currently, there is no State registration of zinc phosphide for controlling muskrats in California.

MANAGEMENT STRATEGIES

There is some question regarding the severity and extent of the muskrat problem along Fall River and the interrelationship with riparian damage attributed to cattle. Some damage is apparent and a large number of muskrats are present along the river. Certainly the Fall River ecosystem has not evolved with the muskrats, as they were introduced to this part of California in the early 1930s (USFWS 1997; Seymour 1954; and Storer 1937). As noted by Miller (1994), muskrat damage is usually not apparent until it is severe and control efforts become necessary.

A study conducted by the USFWS (1997) states that control and/or eradication of muskrat populations in the watershed would be beneficial to Shasta crayfish by reducing sedimentation and loss of habitat and by reducing predation. Eradication of muskrats from the Fall River area is not practical, or even possible, due to their ubiquitous distribution over a large area and adaptive behavior. However, an active, ongoing, and a well-orchestrated control program may help reduce the population to acceptable levels where damage to the river is negligible. Miller (1994) recommends that a systematic assessment of the amount of damage and the costs associated with prevention and control be made before undertaking any control program.

Baseline population surveys must be conducted before implementing population control. This will insure a

baseline population figure to measure success of any control program. Population densities vary widely and depend upon such factors as phase of the population cycle, habitat type and condition, social pressures, competition, harvest, predation, and geographical area. Muskrat carrying capacity depends on habitat and may range from 1.1 to 64.2 per ha (3 to 160 per acre) (O'Neil 1949). This illustrates the need for accurate preharvest population data.

Muskrat houses may be counted from the air, water, or ground over a specified area, band, or transect. Accuracy requires that the observer differentiate between unoccupied and occupied houses and between dwellings and feeding huts or shelters. Muskrat houses are found in areas where cattails or tules line the river and bank slope prevents tunneling. Along steep banks and in areas where lack of suitable vegetation prevents construction of houses, the number of active dens would also need to be counted. House counts should be taken in early fall in order to plan trapping strategies adequately (Dozier 1948). Dozier (1948) proposed using the average number of muskrats per litter as a conversion factor, because during the fall and winter the parent muskrats and their last litter frequently occupy the same dwelling until the spring breeding season.

The California Department of Fish and Game uses a muskrat population model to calculate impacts from hunting and trapping (CDF&G 1996). This model uses the number of adult muskrats per kilometer of stream at the beginning of their spring breeding season. Although some managers argue that muskrat populations are immune to over harvest, cases where over harvest has occurred on a local scale have been reported (Lay 1945; Smith et al. 1981). Smith et al. (1981) produced a harvest model for an exploited muskrat population in Connecticut. The model indicated that a harvest rate of 74% of the autumn population produced an optimal sustained yield. Higher rates led to substantial reductions in total harvest (Boutin and Birkenholz 1987).

In another study (Parker and Maxwell 1984) made preharvest population surveys at three locations in New Brunswick. Trapping was then used to remove 60% of the current population from that area. At one location the population was reduced by 60% during spring months only and at another location the population was reduced by 60% only during autumn months. The third area had the population reduced by 60% during both spring and autumn seasons. Populations harvested during both spring and autumn declined sharply, whereas the areas harvested during spring or autumn months only, showed no decline. Private fur trappers have trapped the Fall River Valley area long before muskrats were introduced into the river system. During a period from the late 1970s to the mid 1980s, when muskrat prices were at their highest, as many as eight trappers worked the river system for muskrats. Their trapping efforts started in mid-November and continued through the end of March (the muskrat trapping season). The remaining adults started breeding during the spring months, quickly repopulating to preharvest levels, which caused continued bank damage until fall trapping reduced their numbers. Even during the highest take years, a harvest level above 75% was probably never met.

Trapping is a feasible way to regulate muskrat numbers (Cook 1952) and the steel leghold and conibear traps are very effective tools to capture muskrats. Regardless, any control effort for Fall River must recognize that muskrats from surrounding areas will recolonize habitat which is trapped (Takos 1994). To be effective, a control program should be conducted year round or at a minimum during both spring and fall periods.

During the mid 1970s, the California Legislature passed a bill which prohibited Federal, State, County and local governments from paying bounties for birds or mammals. Muskrats can be legally harvested and sold by licensed fur trappers from November 16 until March 31. Muskrats causing damage may be taken all year without a permit. Muskrats taken from April 1 until November 15 under depredation purposes may not be kept or sold. Any control program would need to hire salaried employees to do depredation work or depend on volunteer labor.

CONCLUSIONS

Although the muskrat has only been present in Northeastern California for the past 70 years it has become established in wetland areas. Early attempts to eradicate the species met with little success. Any future management should focus on long term goals and commitment. Acceptable limits for damage need to be developed, as well as goals for a workable management plan. Muskrat population surveys and creating a system to measure damage at current levels and for future monitoring need to be addressed. It is essential that all the possible problems and solutions be considered. If muskrat control is possible and it contributes to an improvement in stream and stream bank conditions, and also fosters a sense of "teamwork" among landowners, local groups and outside professionals, than it will be well worth the effort.

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