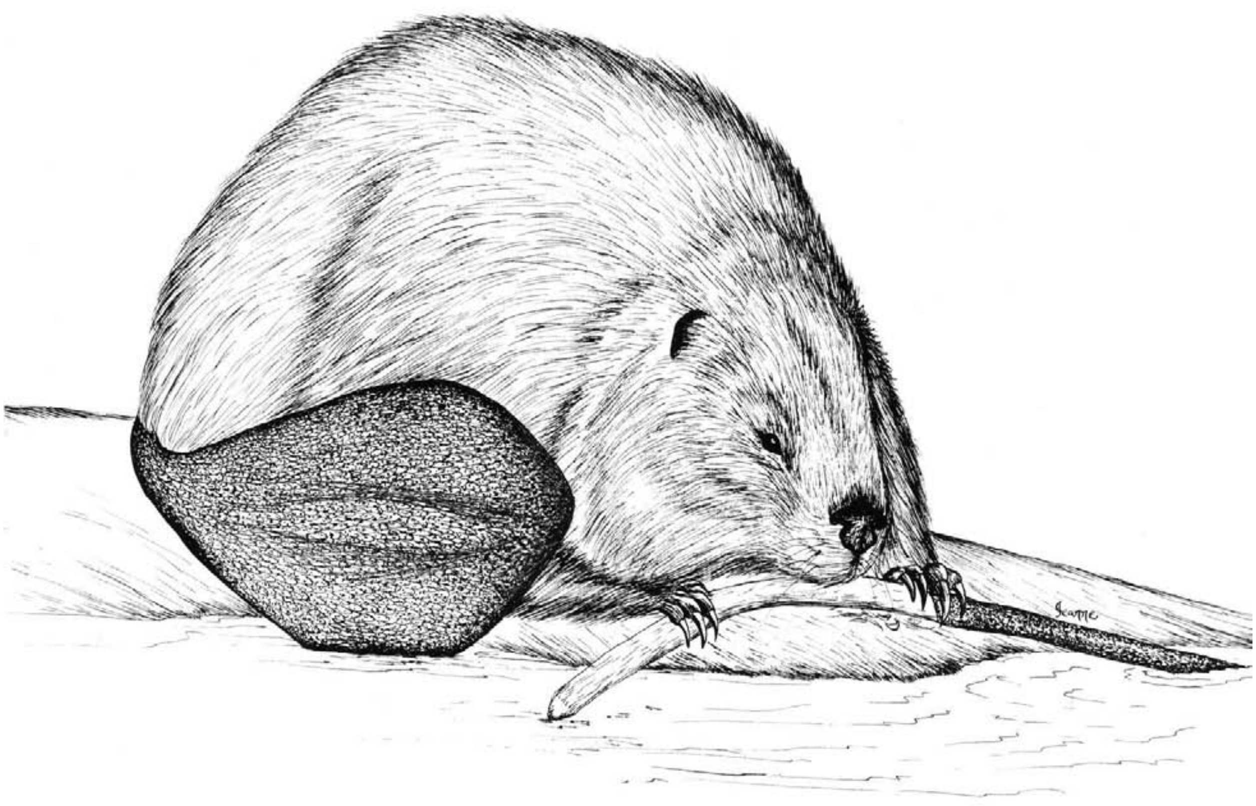
Beaver Management in Pennsylvania

(2010-2019)

Draft 3

prepared by
Tom Hardisky

Last revision: 10/06/2010



"So important was the pursuit of the beaver as an influence in westward movement of the American frontier that it is sometimes suggested that this furbearer would be a more appropriate symbol of the United States than the bald eagle." -- Encyclopedia Americana 12:178, 1969.

EXECUTIVE SUMMARY

Native Americans maintained a well-calculated balance between beaver populations and man for centuries. The importance of beavers to the livelihood and culture of native North Americans was paramount. When western civilization nearly wiped out beavers in Europe, then successfully proceeded to do the same in North America, the existence of beavers was seriously endangered across the continent. Native American respect for beavers was replaced by European greed over a 300-year period. Conservation-minded individuals and state agencies began beaver recovery efforts during the early 1900s. The return of beavers to most of North America was a miraculous wildlife management achievement. Today, the value of beavers as wetland habitat engineers, ecosystem managers, and sources of outdoor enjoyment far outweighs their economic worth. Beavers are an invaluable furbearer resource clearly recognized in Pennsylvania and across North America.

In keeping with our agency mission, beavers must be managed for the benefit of other wildlife species, their habitats, and all Pennsylvanians for generations to come. Our beaver management mission is to establish stable beaver populations in balance with their habitat for the benefit of wetland wildlife species and humans through proper population monitoring, harvest management, and damage control. The goals of Pennsylvania's beaver management are to (1) establish sustained beaver populations within suitable habitat, (2) monitor the beaver harvest, (3) minimize beaver damage complaints, (4) increase public awareness and knowledge of the benefits of beavers and their habitat, and (5) provide opportunities to use and experience beavers.

The purpose of this plan is to provide a comprehensive overview of the current state of knowledge pertaining to beaver biology, habitat, history, damage control, resource and economic value, and population management and provide direction for future management. It represents our guide to managing beaver populations in Pennsylvania for the next 10 years. It also serves as an information and education resource for anyone seeking answers to questions concerning beaver life history and past, present, and future beaver management in the Commonwealth.

Objectives defined in the plan identify the necessary steps to achieve each of the five goals. Strategies consisting of actions and research needs were developed to attain each objective. Improved population and reproductive monitoring, harvest management, habitat assessment, population management on public lands, trapping regulations, damage management, outreach, public engagement, and youth participation are among the most important needs identified.

Pennsylvania's beaver management plan provides the necessary direction to achieve enhanced population, habitat, and harvest monitoring, improved beaver damage understanding, tolerance, and problem resolution, increased public awareness and knowledge of beaver-provided benefits, and sustained resource opportunities for both consumptive and non-consumptive users of this valuable animal in Pennsylvania. Only through careful planning and sound science will we maintain a healthy balance between beavers and humans, and establish and manage sustained beaver populations, much like the Native Americans did centuries ago.

MISSION, GOALS, OBJECTIVES, AND STRATEGIES

Mission: Establish stable beaver populations in balance with their habitat for the benefit of wetland wildlife species and humans through proper population monitoring, harvest management, and damage control.

GOAL 1. Establish sustained beaver populations within suitable habitat.

Objective 1.1. Annually monitor beaver status and population trends.

Strategies

1.1.1. Determine population status from annual furbearer surveys.

1.1.2. Estimate population size or trend within each Wildlife Management Unit (WMU) or other defined unit from annual beaver colony surveys.

Objective 1.2. Assure accuracy of population monitoring methods by 2012.

Strategies

1.2.1. Train survey personnel to accurately recognize and record beaver activity, sign, and structures.

1.2.2. Develop and test a field technique to estimate family group size based on characteristics of constructed features (age, number, and height of dams, condition of lodge/den, food cache size).

Objective 1.3. Develop a model to monitor population changes within each WMU or other defined unit by 2013.

Strategies

1.3.1. Estimate age- or age class-specific fecundity.

1.3.2. Estimate age- or age class-specific mortality from the harvest and other causes.

1.3.3. Determine how beaver regulations such as bag limit, season length, trap distance from beaver structure, and number and type of trapping devices permitted influence the harvest.

Objective 1.4. Develop a geographic information system beaver habitat suitability model by 2012.

Strategies

1.4.1. Identify and map suitable habitat features necessary for beaver occupancy.

1.4.2. Map unoccupied, but potential beaver habitat.

Objective 1.5. Evaluate the practice of beaver trap and transfer for establishing colonies in new locations by 2016.

Strategies

1.5.1. Determine movement patterns and survival of relocated beavers.

1.5.2. Evaluate the cost of trapping and transferring beavers.

1.5.3. Evaluate habitat characteristics of relocation sites, season of year at time of release, and age of released trap-and-transfer beavers that resulted in successful and unsuccessful population establishment.

Objective 1.6. Manage beaver populations on public lands for maximum wildlife benefit.

Strategies

1.6.1. Integrate beaver habitat needs into the state game lands planning process to benefit beaver colony establishment and long term food supply.

1.6.2. Trap and transfer nuisance beavers to suitable habitat to establish new colonies if ecologically and fiscally feasible.

1.6.3. Establish protected beaver colonies on selected state game lands to create population refuges from which range expansion can occur.

GOAL 2. Monitor the beaver harvest.

Objective 2.1. Refine current beaver harvest estimates from furtaker mail surveys to monitor harvest trends by 2012.

Strategy

2.1.1. Establish a means of refining mail survey harvest estimates based on comparisons of actual harvests determined from mandatory tagging with harvest estimates from furtaker mail surveys during the same years.

Objective 2.2. Explore methods of obtaining more precise harvest estimates in areas requiring more accurate harvest monitoring by 2013.

Strategy

2.2.1. Examine options available for mandatory beaver harvest reporting or checking.

Objective 2.3. Develop additional measures of harvest trends by 2013.

Strategy

2.3.1. Determine measures of catch per unit effort by adding trapping effort questions to the annual furtaker survey or point of sale surveys.

Objective 2.4. Develop more understandable beaver regulations by 2012.

Strategies

2.4.1. Review beaver season limit, trapping regulation descriptions, and beaver structure definitions in the Hunting and Trapping Digest to improve trapper understanding of these terms.

2.4.2. Define beaver structures such as lodge, bank den, dam, and feed bed and incorporate them into state regulations.

GOAL 3. Minimize beaver damage complaints.

Objective 3.1. Evaluate the frequency and extent of beaver damage complaints annually.

Strategy

3.1.1. Annually survey agency staff to obtain the number of beaver damage complaints received and information on type of damage.

Objective 3.2. Assess the need for public outreach and engagement regarding beaver damage by 2013.

Strategy

3.2.1. Conduct a survey to determine the public's knowledge of beavers, benefits of beaver habitat, and options for damage control as well as the public's desired beaver population level.

GOAL 4. Increase public awareness and knowledge of the benefits of beavers and their habitat.

Objective 4.1. Develop guidelines for managing beaver family groups on private land to maximize wildlife use and wetland longevity by 2013.

Strategies

4.1.1. Prepare a Game News article or brochure describing the benefits of a beaver colony and how to manage it for maximum wildlife use.

4.1.2. Develop a web page focusing on beaver life history and habitat benefits.

Objective 4.2. Promote the environmental benefits of beavers by 2014.

Strategy

4.2.1. Incorporate information about beaver ecology and how beaver habitat benefits other wildlife into agency educational materials.

GOAL 5. Provide opportunities to use and experience beavers.

Objective 5.1. Annually allow a regulated trapping season for beavers.

Strategies

5.1.1. Establish an annual regulated trapping season for beavers to include the period of maximum pelt primeness.

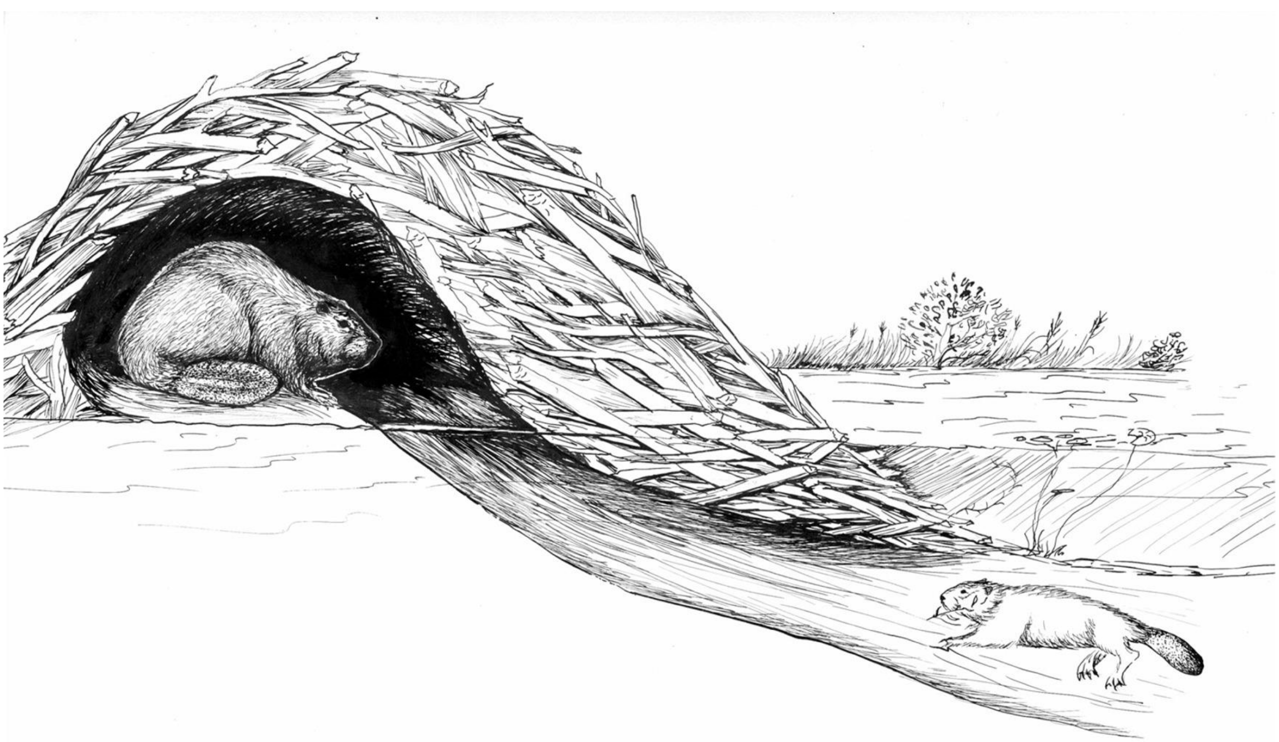
5.1.2. Investigate the possibility of establishing a youth-mentored trapping program to include beaver taking.

Objective 5.2. Develop wildlife viewing opportunities in beaver wetlands.

Strategy

5.2.1. Establish interpretive wildlife viewing areas on state game lands that highlight the contributions of beaver engineering.

TABLE OF CONTENTS



Artwork courtesy of
Dr. Jeanne Jones
Department of Wildlife & Fisheries
Mississippi State University

SECTION 1: BIOLOGY

Taxonomy

Only two species of beavers exist in the world. The North American beaver (*Castor canadensis*) is a member of the Order Rodentia, Family Castoridae, and Genus *Castor*. The similar-looking Eurasian beaver (*C. fiber*) is found in portions of Europe and Asia. North American and Eurasian beavers are so closely related that they probably should be regarded as a single species separated only by geography (Wilsson 1968).

Fossil record of beavers began in the Oligocene Epoch of the Cenozoic Era, Tertiary Period, some 65 million years ago. Several evolutionary lines developed including the burrowing Miocene beaver (*Paleocastor*) which dug corkscrew-shaped underground passages. Another line led to giant beavers (*Castoroides*) that were the size of bears in North America during the Pleistocene Epoch. Fossil remains of these Pleistocene beavers were discovered in Bucks, Montgomery, and Monroe counties, Pennsylvania (Rhoads 1903). Throughout their evolutionary history, castorid beavers have been restricted to the Northern Hemisphere (Vaughan 1978).

Hall (1981) identified 24 subspecies of beavers in North America. Widespread gene pool mixing of some subspecies occurred in areas where beavers were extirpated, then reintroduced. This relocation and mixing of beaver subtypes may have completely eliminated some subspecies (Baker and Hill 2003). Because of the extirpation and reintroduction history of beavers in Pennsylvania, the existence of one distinct subspecies is unlikely.

Common names of the North American beaver include beaver, American beaver, Canadian beaver, and el Castor. The word *beaver* comes from the old English word *beofor*. To some Indian tribes in Canada, the word *beaver* means *little people* (Hill 1982).

Distribution and status

The beaver was the motivating influence in the exploration and conquest of the North American continent. During the 1700s and 1800s, beavers were nearly driven extinct across their North American range (Novak 1987). Prior to this human-induced change in distribution, beavers were thought to occupy all areas of North America where food and water resources were suitable for winter survival (Bryce 1904). Beaver numbers were estimated at 60-400 million prior to European settlement (Seton 1929).

Today, beavers are associated with slow-flowing waterways and wetlands in or near forests and with watercourses in some agricultural areas across North America (Deems and Pursley 1983, Fig. 1).

Fig. 1. North American distribution of beavers depicted by shaded area. Map was created by Deems and Pursley (1978), then modified by Hill (1982).

Food and water availability limit beaver distribution across its range. In Alaska and Canada, beavers are absent north of the tree line. They are also absent from peninsular Florida, portions of the Midwest, and arid regions of the southwestern United States. Beavers occur in northern Mexico along several northern rivers within the state of Sonora, approximately 200 km from the United States border (Gallo-Reynoso et al. 2002).

Although once extirpated from Pennsylvania, beavers currently range across the entire state (Fig. 2) with the exception of small areas in the southeast. In a 2008 Pennsylvania Game Commission Wildlife Conservation Officer (WCO) survey, field officers reported that beaver populations were well established throughout Pennsylvania except for scattered WCO districts primarily in the southern half of Pennsylvania (Fig. 2). Beaver populations were absent from one district in Berks County. It appears that there are no habitat deficiencies in the southeastern portion of the Commonwealth. Excessive trapping pressure and lack of beaver damage tolerance by landowners resulted in a lack of new beaver colony establishment in this area.

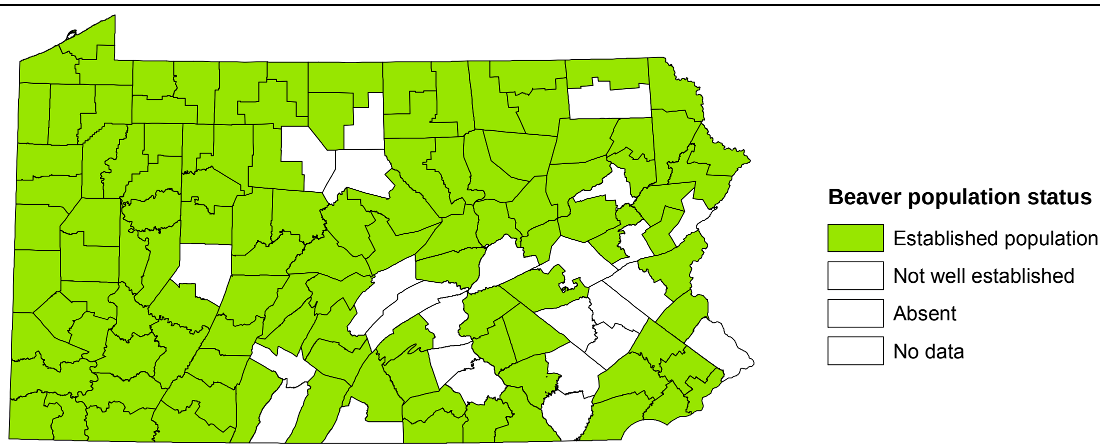


Fig. 2. Pennsylvania beaver distribution and population status in 2008 based on a survey of Wildlife Conservation Officers. Subdivisions are Wildlife Conservation Officer district boundaries.

Physical description

The beaver is the largest rodent in North America with adults averaging 14-29 kg (30-65 lbs). Several beavers in excess of 32 kg (70 lbs) have been taken in Pennsylvania. Total body lengths of 89-135 cm (35-53 in) and tail length 24-45 cm (10-18 in) are common in Pennsylvania (Doutt et al. 1977). Compared to the larger rear half of its body, beavers have a disproportionately smaller head and front shoulders.

Beaver skulls are built strongly and compactly to support their powerful muscles and teeth. Incisor teeth are colored orange and grow continuously throughout life. The hard, enameled front surface of the incisors functions as the sharp edge used to cut trees and peel bark. The rear side of the incisors is softer and wears more easily, creating a beveled, chisel-like edge. The width of individual incisors is normally > 5 mm (3/16 in). When distinguishing beaver damage from other rodent damage, this tooth-mark width can be used to help identify the nuisance animal (Hill 1982). The hypsodont cheek teeth grow only through the deposition of cementum at the bases of the roots. The dental formula for beavers is I 1/1, C 0/0, P 1/1, M 3/3 = 20 (Doutt et al 1977). Their premolars are deciduous and are replaced at about 11 months (Cook and Maunton 1954). The beaver skull's unique basioccipital pit and long auditory bulla that extend upward and outward (Fig. 3) distinguish it from other rodents (Jones and Manning 1992).

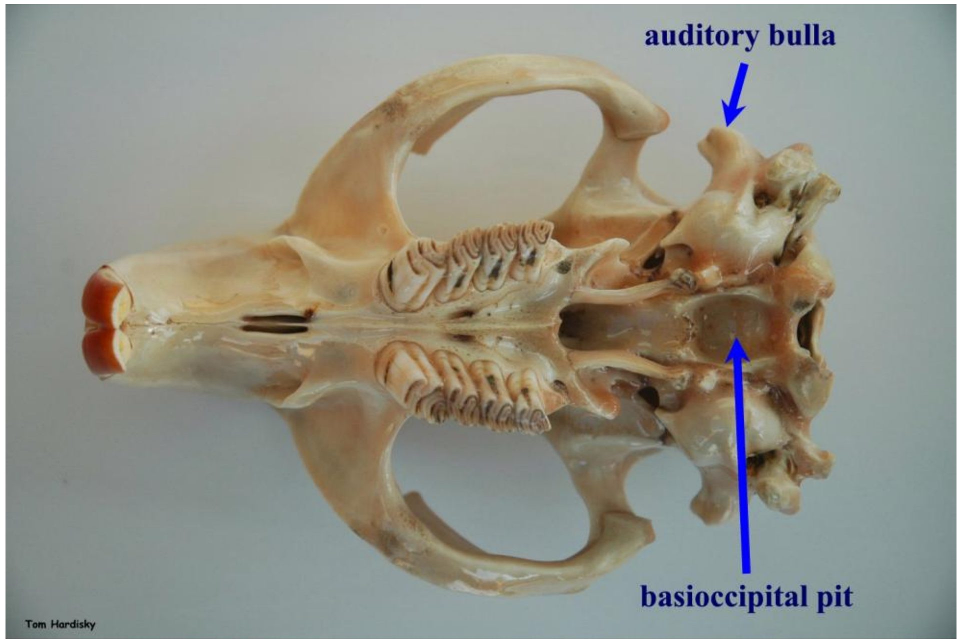


Fig. 3. Ventral view of a beaver cranium depicting the basioccipital pit and long auditory bulla which extend upward and outward. These features distinguish beaver skulls from those of other rodents.

Beavers are semi aquatic and possess physical features that make them well adapted to a water environment and to the dark, humid enclosed spaces of their burrows and houses. Out of water, beavers appear hump-backed and are clumsy walkers. In water, beavers are sleek and torpedo-shaped. They propel themselves with large, powerful hind webbed feet. On the hind feet, the second inside toe has a moveable split nail that the beaver uses for grooming. Their front feet are not webbed, but are dexterous, heavily-clawed, and well-suited for digging. While swimming, the front feet are held against their chest. Swimming speeds in excess of 2 m/sec (4.5 mi/hr) have been recorded (Wilsson 1971). Their flattened scale-covered tail aids in maneuverability while swimming. Beavers also use their tails to balance themselves on land (Rue 1964), signal danger (Wilsson 1971), store fat for the winter (Aleksiuk 1970*a*), and exchange heat (Aleksiuk 1970*a*; Cutright and McKean 1979).

Beavers have dense pelage consisting of a protective layer of guard hairs and a thick layer of underfur, providing insulation and a waterproof barrier. Fully-grown guard hairs are 5-6 cm (2.0-2.4 inches) long, while underfur is 2-3 cm (0.8-1.2 inches) at maximum length (Obbard 1987). Guard hairs are black to reddish in color and are about 10 times the diameter of the underfur, giving the pelt a coarse appearance (Hill 1982). Guard hair density and length is greatest along the back. Individual hairs of the underfur are extremely dense and wavy, giving the pelt a downy softness. The color of the underfur is black to gray. Beavers have one annual molt, occurring during the summer.

A multitude of beaver pelt color patterns exist, ranging from blond to nearly black. Beavers often have variable pelt coloration within and among populations. During fur grading, however, eastern U.S. beaver pelts normally fall into the dark color category (Obbard 1987). Coloration of an individual guard hair is usually consistent throughout its length. Underfur of the pelt may be dark gray to chestnut in color on the back. Like guard hairs, underfur color becomes lighter along the sides and ventral area. Albino beavers are extremely rare, but have been documented (Ontario Ministry of Natural Resources, unpublished report).

The eyes, nose, and mouth are valvular, closing when beavers dive underwater. Beavers have transparent eyelids (nictitating membranes) that protect their eyes while swimming under water. These structures protect the eye surface from suspended abrasive particles in the water. The location of the eyes near the top of the skull and midway between the nose and skull base allows beavers to see above the water while swimming. These adaptations enable beavers to swim with minimal exposure above the water surface. Beavers have small eyes and nearsighted vision. Nearsightedness is a possible adaptation advantageous to its nocturnal lifestyle. Beavers have a keen sense of smell and acute hearing for detecting food and danger.

Beavers have fur-lined lips that close behind the incisors, allowing them to cut and carry sticks underwater. Two specialized structures enable beavers to open their mouths while gnawing underwater or carrying branches without danger of taking water into their lungs. The epiglottis is positioned above the soft palate allowing the efficient transfer of air from the nasal passages to the trachea, but not allowing panting or mouth breathing (Cole 1970). Another structural specialization is the elevated rear portion of the beaver's tongue that fits tightly against the palate. Except when swallowing, the tongue blocks the passage to the pharynx (Cole 1970).

The digestive system of beavers is adapted to utilize cellulose. Beavers are hind-gut fermenters (Baker and Hill 2003). Digestion is enhanced by an unusual cardiogastric gland in the stomach, a glandular digestive area, and a large tri-lobed cecum containing beneficial microorganisms (Vispo and Hume 1995). Beavers maximize the nutritional value of woody plants by consuming only the bark. They can digest 32% of available cellulose by microbial action in the cecum (Buech 1984). A beaver's small intestine is relatively long, suggesting a high absorption capability (Vispo and Hume 1995).

Beavers practice coprophagy (consumption of feces). They consume soft green excrement directly from the cloaca. The fecal material is chewed, reingested, and passed quickly through the digestive system (Buech 1984). This practice is believed to improve digestive efficiency and has been observed as early as 10 days of age (Wilsson 1971).

Beavers can remain submerged under water for as long as 15 minutes (Irving and Orr 1935). They have the ability to exchange as much as 75% of the air in their lungs, as compared to only 15% for humans, and can tolerate high concentrations of carbon dioxide in their lungs (Rue 1964). When held underwater, beavers do not drown from water inhalation into their lungs like most mammals. Carbon-dioxide narcosis gradually occurs, but water never enters the lungs. Gilbert and Gofton (1982) reported a reduced heart rate in beavers while they were diving (67 beats/minute) as compared to when they were swimming (125 beats/minute).

The reproductive organs of both sexes are internal and lie in front of a common anal cloaca containing castor and anal glands (Svendsen 1978). The cloaca is a single opening serving as the urinary and bowl exit point, the male and female sex organ covering, and the castor and anal gland secretion port. Beavers comb oil produced by the anal glands into their fur to waterproof it

(Walro and Svendsen 1982). Ducts from the castor glands join the urethra. Urine washes the exudates from within the castor glands producing castoreum (Svendsen 1978). Beavers frequently expel castoreum and anal gland secretions into the cloaca. Both have strong, pungent odors that are used for scent communication.

Some external beaver characteristics can be used to differentiate sexes. Females nearing parturition or during lactation have 4 pectoral mammae, easily visible on the chest. Male beavers have bacula that increase in size with age (Friley 1949). The sex of live beavers and unskinned carcasses can be determined by palpation for the baculum which is positioned anterior to the anal cloaca (Svendsen 1978). When carefully palpated, presence or absence of a baculum is an accurate sexing method for beavers (Osborn 1955).

Reproduction

Beavers breed over a longer period of time (November-March) in warmer, southern regions of North America than in colder, northern areas (Miller 1948, Henry and Bookhout 1969, Wigley et al. 1983). Female beavers mate for life, but males are sometime polygamous (Hill 1982). In Pennsylvania, beavers mate during January-March (Brenner 1964). Mating occurs in bank dens, lodges, or in water.

The gestation period was commonly thought to last 90-100 days in both North American and European beavers. However, the gestation period is now considered to be 105-107 days in European beavers (Wilsson 1971, Doboszynska and Zurowski 1983) and about 100 days in North American beavers (Woodward 1977, Wigley et al. 1983). In Pennsylvania, females give birth to precocial young during April and May (Brenner 1960). Young beavers (kits) are born fully furred and able to walk and swim within 4 days (Wilsson 1971). Average weights of newborns have been reported at 335-495 g (12-17 oz; Shadle 1930, Bradt 1939). Most kits weigh about a pound at birth, but may be smaller in large litters.

In general, sexual maturity in beavers is reached between 1.5 and 3.0 years of age. There are no reports of female kits (<12 months old) breeding in captivity or the wild. With some regional variation, beavers can reach sexual maturity as yearlings (1.5-2.0 years old), averaging 21 months of age (Henry and Bookhout 1969, Wigley et al. 1983). Brenner (1964) did not find sexual maturity among yearling beavers in northwestern Pennsylvania and very little breeding (24%) among 2-year-old adults. He estimated the age of beavers based on weight and pelt size. In northeastern Ohio, Henry and Bookhout (1969) determined age based on tooth eruption, basal closure, and cementum annuli counts and found that 40% of yearlings and 78% of 2-year-old beavers had ovulated.

Habitat quality and nutritional plane has been related to age at first breeding (sexual maturity), age of dispersal, and litter size (Huey 1956, Gunson 1970). Beavers tend to breed at younger ages and have greater reproductive potential in areas of good or excellent food quality and habitat conditions, particularly those containing aspen. Body size, rather than age, is more closely correlated to sexual maturity and first breeding (Gunson 1970).

Beaver population density with respect to habitat availability and exploitation may relate to age of sexual maturity. Parsons and Brown (1979) noted that reproduction in yearlings may cease where >40% of suitable beaver habitat is occupied by established colonies. Boyce (1974) surmised earlier sexual maturity in exploited beaver populations in Alaska. He noted decreased age at first breeding and smaller average body size at maturity among heavily exploited populations

In a review by Hill (1982), he noted a pattern of sexual maturity at age 1.5 to 2 at middle range latitudes, provided food conditions were favorable, some exploitation or predation occurred, and there was room for some range expansion. However, he observed inconsistency in the pattern at northern and southern range limits, where breeding was delayed until age 2.5 or more.

Pregnancy rates among age groups vary. However, pregnancy rates usually increase to about age 4 and remain high among older age groups except in extremely old individuals (Henry and Bookhout (1969). Pregnancy rates in 2.5- and 3.5-year olds are influenced by population structure within colonies and the extent of dispersal. Gunson (1970) believed that there was less dispersal in good-quality habitats and therefore less breeding among young adults in colonies containing older dominant pairs.

Beaver fecundity is density dependent (Gunson 1970, Boyce 1974, Payne 1984*a*). Consequently, in areas where regulated trapping is practiced, we would expect greater reproductive potential. In an unharvested beaver population, Payne (1984*b*) found an average of 1.8 kits per female, while females in harvested colonies averaged 2.9 kits (Payne 1984*a*). In addition to the extent of exploitation, litter size is influenced by food quality and availability.

One litter each year is produced by each family's breeding female (Novak 1977, Wigley et al. 1983). Brenner (1964) estimated litter size in northwestern Pennsylvania at 5.5 per pregnant female, ranging from 1 to 9 embryos. Doutt et al. (1977) listed an average litter size of 4 for Pennsylvania beavers, but likely based their estimate on U.S. regional or national averages. Other than a small section of northwestern Pennsylvania, statewide beaver litter size information is lacking. The sex ratio at birth is 1:1. Variation from this even sex ratio is likely a result of the random fertilization process or sampling differences.

Mortality

In the wild, most beavers do not live more than 10 years, but captive beavers may live to 21 years (Hill 1982). Today, humans are the main predator of beavers. Historically, wolves (*Canis lupus*) filled this predatory role. Timber wolves are the only predator reported to have any significant impact on beaver populations (Potvin et al. 1992). Other mammalian predators including coyotes (*Canis latrans*), river otters (*Lontra canadensis*), bobcats (*Felis rufus*), mink (*Mustela vison*), and bears (*Ursus* spp.) often prey on juvenile beavers, but have little influence on population dynamics. Domestic or feral dogs (*Canis familiaris*) also prey on beavers. Habitat conditions that force beavers to forage farther away from water may cause increased predation rates. As food supplies dwindle near the water's edge, beavers are forced to spend more time on land to seek food. Beaver predation vulnerability is greatest on land. Other than wolf predation, no study has shown that beaver populations have declined as a result of predatory loss.

Prenatal mortality caused by resorption of the fertilized egg or abortion of the embryo can be substantial. Most embryonic deaths occur early in the pregnancy. Reported preimplantation losses ranged from 3.8-38.2% and postimplantation mortality of embryos was an additional 2.7-17.2% (review by Hill 1982). Although not well documented, severe climatic conditions may cause excessive prenatal losses (Harper 1968).

Mortality from birth through the first two years is minimal. Gunson (1970) estimated a 2.7% mortality rate for kits during their first summer. Novak (1977) found that kit mortality from birth to the first winter was not significant. Losses in the kit as well as the yearling age classes are minimal (Cook 1943, Shelton 1966). The safety afforded by life in a family group appears significant.

Mortality of young beavers that disperse from their parental family group can be substantial. Weaver (1986) reported a 44% mortality of dispersing beavers in Mississippi. He surmised that dispersal into unsuitable or marginal habitats may have decreased their chance of survival. Bergerud and Miller (1977) estimated a combined mortality rate of 46% for kits, yearlings, and 2-year-olds and only 12% for those older than 3 years. Mortality rates are highest during the first 2-3 years of life and lowest between the ages of 5 and 9 years (Gunson 1970). Payne (1984*b*) reported mortality rates of 4% for beavers 0.5-1.5 years old and 40% for 1.5-2.5 year olds in regularly-trapped areas. In areas previously trapped out, he reported mortality rates of 0% for 0.5-1.5 year olds, 60% for those 1.5-2.5 years old, and 25% for beavers older than 2.5 years. He also found no difference in mortality between sexes. Gunson (1970) estimated that only 3-6% of beavers survive to age 10 and 1% to age 20.

Beavers appear to be less affected by diseases than many other species. However, tularemia, caused by the bacterium *Francisella tularensis*, can cause massive die-offs in local epizootics. During the winter of 1951-52, Knudsen (1953) estimated 10,000-15,000 beaver deaths from a tularemia outbreak in Wisconsin. Water-borne type B tularemia (*F. t.* biovar *palaearctica*) commonly occurs in both beavers and muskrats (Baker and Hill 2003). Type B tularemia is not fatal to humans and occurs in only 5-10% of human infections. Type A tularemia (*F. t.* biovar *tularensis*) can also affect beaver populations, but is of particular concern to humans since this type is a life-threatening disease. Tularemia in beavers causes fluid build-up in the thoracic and abdominal cavities, stomach and intestine inflammation, and small white to gray areas of necrotic tissue on the liver, spleen, kidneys, and mesenteric lymph node (Davidson 2006).

Parasites infrequently occur in beavers and do not appear to control beaver numbers. However, if they occur in very large numbers and are associated with tissue damage, parasites can cause mortality. Beavers are hosts for several ectoparasites including ticks (*Ixodes banksi*) and beaver beetles (*Platypsyllus castoris* and *Leptinillus validus*) that eat dandruff (Gibson 1957). Endoparasites including several species of nematodes, trematodes, and coccidians have been found in beavers (Miller and Yarrow 1994).

Some species of *Giardia*, protozoan parasites, are carried by beavers, but do not appear to severely affect them. Especially in dense populations, beavers can carry and spread waterborne

Giardia spp. cysts as well as microsporidia species (Fayer et al. 2006). *Giardia lamblia* is an intestinal parasite in beavers that can cause human health problems in water supply systems.

Non-predatory mortality sources include starvation, unusual weather events, and accidents. Mortality can occur as a result of a winter food cache being too small (Gunson 1970). Malnutrition or starvation can result from lack of a sufficient winter food store. Mid-winter snowmelts and violent spring breakups can destroy lodges and occupants or drown a large number of beavers (Hakala 1952, Boyce 1974). Accidental deaths from falling trees are generally rare, but occur occasionally. Highway accidents caused by motor vehicles are not common, but can be significant in high traffic areas.

Food Habits

Beavers in North America consume many different species of both woody and herbaceous plants. Leaves, twigs, and bark of trees and shrubs as well as stems and leaves of aquatic, herbaceous vegetation are eaten by beavers. They are generalized herbivores, but have seasonal food preferences. Trembling aspen (*Populus tremuloides*) is the beaver's most preferred woody food across its range. In Pennsylvania, Brenner (1962) found that beavers utilized 95% of aspen and 18% of red maple (*Acer rubrum*) available within food quadrats. Red maple was the second-most preferred beaver food. Other common tree species include willow (*Salix* spp.), other maples (*Acer* spp.), oak (*Quercus* spp.), birch (*Betula* spp.), alder (*Alnus* spp.), and white pine (*Pinus strobus*). Tree cutting may occur during any season, but most woody species foraging occurs in late autumn and as cached food during the winter. Brenner (1960) estimated daily consumption of woody foods at about 559 g (20 oz).

When available, aquatic vegetation may be preferred over woody plants. Jenkins (1981) found that water lilies (*Nymphaea* spp.) with their thick fleshy rhizomes were preferred over woody vegetation during all seasons in Massachusetts. Other aquatic, herbaceous foods include burreed (*Sparganium* spp.), St. Johnswort (*Hypericum* spp.), duck potato (*Sagittaria* spp.), duckweed (*Lemna* spp.), pondweed (*Potamogeton* spp.), water weed (*Elodea* spp.), and sedges (*Carex* spp.) (Collins 1976, Brooks et al. 1993). If present in adequate amounts, aquatic vegetation can provide enough winter food and result in no or very little tree cutting or food caching of woody material (Jenkins 1981).

Upland herbaceous foods are also consumed by beavers. In Mississippi, Roberts and Arner (1984) used stomach analysis to assess food habits. They found that beavers consumed 42 species of trees, 36 genera of herbaceous plants, 4 types of woody vines, and many species of grass. Included in the types of forb species found were rice cutgrass (*Leersia oryzoides*), golden club (*Orontium aquaticum*), giant cane (*Arundinaria tecta*), poison ivy (*Toxicodendron radicans*), soybean (*Glycine max*), and pondweed.

Beavers can inhabit and sometimes thrive in areas where preferred foods are uncommon or absent (Jenkins 1975). They have subsisted in some areas by feeding on coniferous trees, which are generally considered a poor quality food source (Brenner 1962). In southcentral Alaska, beavers were observed feeding on discarded Chinook salmon carcasses on three separate occasions between 1999 and 2004 (Gleason et al. 2005). This foraging behavior may be fairly common in Alaskan streams and rivers to take advantage of a seasonally abundant protein source.

Behavior

Some of the most detailed behavioral studies conducted on beavers were completed by Wilsson (1968, 1971). Comparing the behaviors of young, European beavers (*Castor fiber*) raised in isolation with wild beavers raised under normal environmental conditions, he was able to distinguish innate from learned behaviors among these animals. Beaver activities such as building dams and lodges, digging, manipulating food, moving materials, and creating food caches were behaviors that involved little or no learning. Young beavers could transport building materials at 14 days and place sticks in holes by 23 days. At 2 months of age, beavers could dig burrows and make channels. Wilsson's (1971) controlled experiments showed that beavers over 1 year of age will build a dam wherever there is a sound of running water. Beavers built dams on a cement floor against a loudspeaker that played the sound of running water (acoustic stimuli). He concluded that beavers attempted to minimize the sound of running water and that this was clearly innate behavior. He also observed the lack of some beaver behaviors typical of most rodents. He noted that beavers never stretch, nor do they lick, even during grooming. The development of other beaver behavior patterns is described in Table 1.

Beavers will become aggressive if provoked by lunging forward and biting their adversary. Prior to lunging, beavers will usually make hissing sounds and sometimes exhibit tooth sharpening behavior (Wilsson 1971). Captured adult beavers often display both hissing and tooth sharpening behavior when approached. The placement of foreign castoreum upwind from a lodge often elicits investigation, hissing, and tail slapping as beavers emerge in the evening. This response to foreign castor prompted early trappers to use castoreum as bait (Hill 1982).

Building behavior

Dam building in a stream is usually located at a narrow spot where water runs between two or more obstructions such as stones, logs, or debris. Beavers place peeled logs or sticks parallel to the current. Once sticks are anchored across the stream, mud, rocks, and leaves are carried to the upstream side of the dam. As water levels rise, beavers add crisscrossed layers of sticks held together with more mud, detritus, vegetation, and rocks. Water begins to pool, stream velocity decreases, and sediment settles on the new pond bottom. An increase in the amount of surface water provides beavers with expanded, safe access to more trees. Beavers dig channels to facilitate transport of felled trees. They continuously repair leaks in the dam. Within 1-2 years, water-stressed trees and shrubs die, allowing more sunlight to reach the water surface.

Beavers construct lodges for shelter and raising their young. Wilsson (1971) found that beavers only build a lodge when they have become accustomed to their surroundings and have used the building site for sleeping for some time. He also found that locating the lodge building site was a learned behavior. There are two types of beaver lodges: island- and bank-types. Island-type lodges are dome-shaped structures made of sticks and logs plastered with mud. Bank lodges may not be dome-shaped, but are also constructed with mud-plastered sticks and logs. All lodges and bank dens have at least two entrances and may have four or more (Miller and Yarrow 1994). Rising waters activate lodge and dam building, while low water encourages channel dredging and lodge entrance improvement. Young beavers do not assist with dam or lodge construction until their second autumn of life (Wilsson 1971). Construction and repair work is primarily a female task. Beavers within a colony may occupy several bank dens or lodges.

Table 1. Development of beaver behavior patterns (from Wilsson 1971).

Behavior pattern	Age at first performance
Locomotion	
Walking	A few hours
Swimming on the surface	4 days
Diving and swimming underwater	12 days
Fully-developed ability to stay underwater	2 months
Feeding	
Gnawing bark and leaves	4 days
Handling twigs and stalks	14 days
Grasping twigs between 5th digit and the other digits	29 days
Peeling bark	33 days
Cutting and felling small trees	2-5 months
Collection of food stores under water	6 months
Eating leaves in an adult beaver fashion	12 months
Care of fur	
Grooming with forepaws and combing with split nail	4 days
Fully developed grooming	19 days
Mutual grooming within the family group	30 days
Fully developed ability to keep the fur water repellent	60 days
Digging	
Scratching/shoveling/pushing earth with family group	14 days
Shoving, pushing and packing	45 days
Digging a temporary nest	60 days
Digging a tunnel system	1 year
Building of lodges, dams and winter stores	
Carrying and pushing sticks at random	14 days
Dragging	16 days
Placing sticks in holes	23 days
Lodge building	4-5 months
Dam building	6-7 months
Protection against enemies	
Hissing	1 day
Leaping aside	3 days
Seeking protection in the water	10 days
Tail slapping	1 month
Social and territorial behavior	
Exploratory behavior	1 day
Tail wagging	6 days
Aggressive tendencies, wrestling	30 days
Territorial marking	5 months

McNeely (1995) provided an excellent description of beaver den and lodge construction along streams and rivers in his Missouri beaver manual. He noted that beavers often select a high bank or take advantage of soil-holding tree roots to dig a den. Two or three underwater entrances to a den are common. A hollowed-out living chamber inside of the bank den is located 1-2 feet above the water level. Sometimes the digging of the hollowed chamber results in a cave-in of the bank. Beavers thatch over these holes with mud and sticks. These mounds are referred to as *bank lodges* and often extend over the bank. Well-maintained mud and stick thatch freezes solid during the winter and provides excellent shelter and protection from predators.

Winter food caches (feed beds) are constructed during the fall to provide a winter food supply. As a rule, beavers do not create a food cache until they have built or renovated a lodge in the autumn (Wilsson 1971). Food caches usually consist of tree and shrub branches piled underwater outside of the den entrance, providing access under the ice surface throughout the winter. The inner hardwood of tree branches, left after beavers eat the softer, nutritious cambium from the branches, is used for dam and lodge construction. The young of the year do not normally fell trees or assist with feed bed construction until their second autumn (Wilsson 1971).

Movements

Beaver movements within territories and dispersal movements outside of the family home range constitute most travel. Bergerud and Miller (1977) identified four distinct types of beaver movements. They included local movements between ponds within a family group territory, yearling wandering, dispersal of 2-year-olds to establish new family units, and movement of adults who lost their mates.

Daily movements around the lodge and pond are primarily nocturnal. Most feeding and dam construction occurs at dusk and after dark. Activity outside of the lodge is much greater just before dark and in the early morning hours after daybreak. Beavers travel further upstream than downstream to retrieve materials for dam and lodge construction and foraging (Boyce 1981).

Dispersal is important in reducing population pressures and social stress. It also may be the primary means of preventing inbreeding and the primary mechanism of population expansion. Young normally disperse to establish new colonies after their second year. Dispersing beavers of both sexes remain transient until they settle with an unpaired beaver. They often build dams and lodges that may help attract a mate.

Young adults leaving their parental family unit to establish new family groups often travel long distances. Dispersal movements of 82 km (51 mi) have been documented (Beer 1955), but generally average 5-6 miles from the natal family group. Relocated beavers in Wisconsin travelled an average 7.4 km (5 mi) from their release points (Knudsen and Hale 1965). However, long distance movements of 238 km (148 mi; Hibbard 1958) and 241 km (150 mi; Libby 1957) have been documented for transplanted beavers.

Communication

Beaver tail slapping behavior is thought to alert other members of the family unit of danger. Tail slapping is also a diving aid that gives a beaver extra propulsion to tip its body down for descent and may not always be intended to be a danger signal (Doutt et al. 1977). In rodents, a vertical tail stroke against the ground is an expression of excitement and threat (Wilsson 1971). Tail slapping while diving, mimics this behavior. However, tail slapping often occurs without provocation. Frightened beavers commonly submerge without creating ripples in the water and without tail slapping (Doutt et al. 1977).

Wilsson (1971) observed five types of beaver vocalization. Outside of the lodge, beavers mainly used one specific kind of vocalization named the *whistling call*. When beavers wished to contact colony members from a distance, they make a high frequency, whistling sound that can barely be heard by the human ear. Wilsson (1971) noted that the whistling call was often heard in newly-caught young. Hodgdon and Lancia (1983) described two additional vocalizations outside of the lodge: hissing and growling.

Inside the lodge, four types of contact vocalizations were identified by Wilsson (1971). Young beavers whimpered like small children or made a clacking sound when improperly handled. Adults inside the lodge made highly variable, high and low-pitched squeaks when seeking social contact. While feeding, beavers often used a high-pitched whine as another beaver approached. As the distance between the two beavers decreased, the whine became aggressive in tone. Vocalizations that had broad variation were thought to express the mood of the animal.

Scent marking is a highly developed form of communication in beavers. Both sexes have a pair of castor glands, used for olfactory communication, and a pair of anal glands, used for both communication and to give fur water repellency (Novak 1987). The smell of castoreum stimulates territorial behavior among group members. It also plays a role in pair formation (Wilsson 1971). Castor and anal gland secretions are deposited on scent mounds made of piles of mud and debris. Scent mounds are usually placed on or near lodges, dams, and trails within 1 m of water (Baker and Hill 2003). Beavers of all ages create scent mounds. Males place the most scent marks (Hodgdon and Lancia 1983). In Pennsylvania, scent marking occurs throughout the year, and is most intense during late winter and spring (Brenner 1960).

Population dynamics

The number of beavers occupying an area largely depends on habitat and mortality. Beaver colony density increases with the degree of stream channel splitting, available winter food cache materials, and the diversity of vegetation types (Boyce 1981). Although natural predation and disease can sometimes affect beaver numbers, regulated trapping is the primary mortality source where harvest is permitted. Beavers are vulnerable to overharvest. Sign of active beavers is obvious even to inexperienced individuals. Confined to watercourses, their movements and behavior are relatively predictable.

The beaver's vulnerability to harvest often results in local population eradication. Trapper efforts are routinely directed to high-quality habitats. Consequently, mortality from trapping is typically greater in high-quality habitats and less in low-quality habitats (Gunson 1970). Adults seem to be more susceptible than kits or yearlings to winter trapping (Payne 1975).

Long-term shifts in beaver populations in response to changes in harvest and habitat conditions have been documented. Novak (1987) observed a decline in Ontario's beaver harvest during the 1920s to the mid-1930s due to probable overharvest. As a result of proper management, beaver numbers and harvest steadily increased until about 1970. The plotted harvest line was relatively smooth during increasing and decreasing phases (Fig. 4). When beaver populations were at or near saturation levels, the plotted harvest line became saw-toothed. Novak explained that this effect was not a result of rapidly fluctuating populations, but more likely the result of economic and climatic factors influencing the ability or desire of trappers to harvest beavers. A beaver population decline attributed to deteriorating food conditions was reported by Aleksiuk (1970*b*) in Canada's MacKenzie Delta. He observed a population decline of about 20% per year for 4 years.

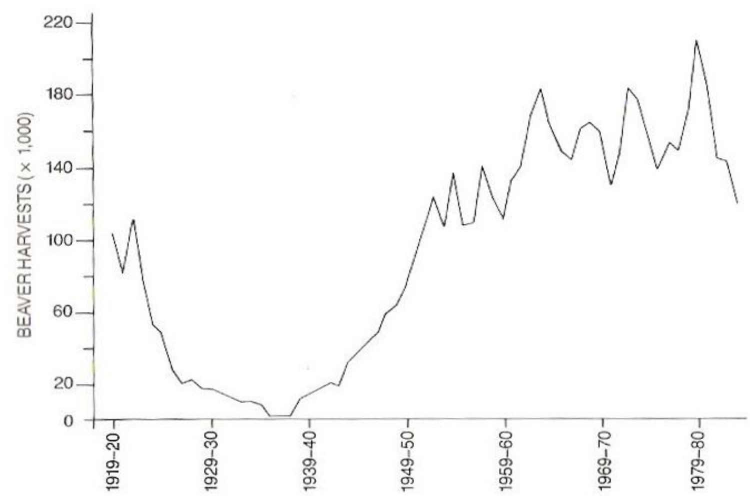


Figure 4. Beaver harvest in Ontario from Novak (1987).

There is no evidence that beaver populations are cyclic. The number of active colonies in an area varies annually. Extreme weather patterns such as drought conditions or severe flooding can decimate a beaver population. Disease outbreaks such as tularemia can also decrease a population for several years (Labzoffsky and Sprent 1952, Knudsen 1953). Favorable habitat conditions developed over time can revive a beaver population in a relatively short period.

Social/Spatial organization

A beaver colony is defined as a group of beavers occupying a common pond or stretch of stream, using a common food supply, and maintaining a common dam or dams (Bradt 1938). Although the term *colony* normally describes a collection of families, it has traditionally been used to characterize a family group of beavers. The terms *colony* and *group* are used interchangeably in reference to beavers sharing common food, shelter, and waterways. Beaver groups or colonies are actually closed, extended-family units. A typical beaver group in mid-winter consists of an adult pair, 2-3 yearlings, 2-4 kits from the previous spring litter, and occasionally one or more 2.5 year olds (Hill 1982). Most colonies consist of 4-8 beavers that are related to one another (Miller and Yarrow 1994). Gunson (1970) found that the number of beavers in a colony was greater in better quality habitats. Also, he found that the number of beavers in a colony appeared to be regulated by variations in litter size and in the frequency of dispersal of immature animals. Lone beavers and mated pairs taking up a new residence away from their parental colonies are sometimes referred to as single colonies and pair colonies (Payne 1975).

Home range is greatly affected by the water system where the beaver family lives. Members of a beaver colony typically show territorial defense of their lodge and pond. The colony resists all outsiders (Miller and Yarrow 1994).

Beavers normally become sexually mature after they leave the parental colony (Wilsson 1968). The social structure of a beaver colony tends to inhibit sexual maturity of the young. Normally, only the dominant female comes into estrus and breeds. Similarly, the dominant male may prohibit young males in the colony from breeding.

Dispersal permits sexual behavior to develop. If good habitat with a sufficient food supply exists, less dispersal and larger colonies will likely result. Lower fecundity would occur under these favorable conditions (Boyce 1974). Likewise, limited food supplies or poor habitat often cause more rapid dispersal of juveniles resulting in breeding at an early age. In a Saskatchewan study area of inferior habitat, Gunson (1970) found high survival of kit beavers during the first few months of life, movements of entire family groups into and out of the study area, and emigration of yearlings from parental colonies in their second summer of life (Gunson 1970).

The spatial distribution of beaver colonies depends on the home range shape and size of their members. Research has not precisely defined a beaver's home range and territory. However, colonies do not share feeding areas, winter food caches, dens, lodges, or ponds with members of another family group. Brooks (1977) found two lake shore family groups that lived only 0.3 km (0.2 mi) apart, but used feeding areas in opposite directions. Home ranges of adjacent family units are usually separated by unoccupied habitat (Baker and Hill 2003).

Home range size and configuration depend on a beaver's sex, age, social position within the family group, habitat type, and seasonal limitations (Baker and Hill 2003). Females with kits tend to limit their distance from the lodge or den, while males range over a larger area. As the young become more independent, home ranges of adults may increase. During the winter, ice confines movements resulting in smaller home ranges. In Manitoba, Wheatley (1997) found that beaver home ranges were larger in the summer and fall than in winter.

Beaver families have been reported to occupy 0.6-1.3 km (0.4-0.8 mi) of stream throughout much of their range (review by Novak 1987). Brooks (1977) reported that an average family occupied 2.5 km (1.6 mi) of shore habitat. A colony's home range size is likely a function of habitat suitability. In the Soviet Union, Semyonoff (1951 cited by Novak 1978) found that families of Eurasian beavers in the best habitat occupied 0.5-0.7 km (0.3-0.4 mi) of stream and were separated by about 150-200 m (490-650 ft) of neutral zone between family groups. In medium habitat, family units occupied 1 km (0.6 mi) of stream with 0.5-1.0 km (0.3-0.6 mi) separation. In mediocre or poor river habitat, families were spaced 5-10 km (3-6 mi) apart.

SECTION 2: HABITAT

In North America, beaver ponds and dams number in the millions. No other animal besides humans has bestowed such a dramatic impact on the environment. Beavers are often credited with the ability to create their own habitat. Although they are dependent upon growth of plant life for food, beavers do create their own escape cover and shelter.

Prior to European settlement in North America, beavers diversified the landscape by providing wetland patches in a primarily forested region (Hill 1982). These patches of wetland created a highly productive system due to the abundance of water and nutrients. Native Americans used abandoned, sediment-rich, beaver ponds for growing crops because of the soil's high fertility (Hilfiker 1991). Beaver wetlands provide habitat diversity by creating temporally shifting patches of flooded trees and shrubs, aquatic emergent plants, open water, and edge. These habitat features support diverse types of wildlife as well as many rare wetland plants and animal species.

Habitat description

Beavers can survive in areas with poor food conditions, but cannot survive for long in waterways with seasonally fluctuating water levels or swift current. They do not prefer rocky streams or lakes with rocky shores. Houses and feed beds are rarely built on large lakes with excessive wave action. Flood-prone areas with widely fluctuating water levels are avoided. Preferred sites include ponds, small lakes with muddy bottoms, and slow-moving streams. Beavers will reside in artificial ponds, reservoirs, and drainage ditches if nearby food is available.

Suitable habitat for beavers must contain all of the following: 1) stable aquatic habitat providing adequate water depth, 2) channel gradient of less than 15%, and 3) quality food species present in sufficient quantity (Williams 1965). In the northern beaver range including Pennsylvania, beavers need adequate forage for construction of a winter food cache, herbaceous vegetation for summer feeding, and a body of water of sufficient depth and size to contain a food cache and provide escape cover from terrestrial predators (Boyce 1981).

Beavers exist in three main types of aquatic systems: 1) beaver ponds created by constructing dams across streams, 2) edges of existing lakes or large ponds, and 3) within large rivers and streams where water flow is too strong to build a lasting dam. Beavers dig bank dens in areas where the water current is strong or where woody material is scarce. Conical-shaped lodges are constructed on low-flow streams, lakes, and ponds. Beavers will live in close proximity to humans as long as basic habitat requirements are met (Rue 1964).

A habitat suitability index model for beavers used to evaluate existing or potential habitat was developed by Allen (1982). Significant habitat variables were identified and optimal levels were quantified. Aquatic habitat cover types used in the model included palustrine (herbaceous, shrub, and forested wetlands), riverine, and lacustrine. The habitat survey area was a 200 m (656 ft) band around the water source and included the water surface for water systems ≤ 8 ha (20 ac) in size. The following habitat conditions rank highest in suitability for beaver habitat in the model:

- ≤ 6% stream gradient
- small water fluctuations that have no effect on burrow or lodge entrances
- 40-60% tree/shrub canopy closure
- 100% of trees in the 2.5-15.2 cm (1-6 in) dbh size class
- 40-60% shrub crown cover
- ≥ 2 m (6.6 ft) average height of shrub canopy
- ≥ 50% of woody vegetation dominated by aspen, willow, or alder
- lake surface dominated by yellow and/or white lily (*Nymphaea* spp.)
- ratio of lake shoreline length to lake area ≥3 using diversity index formula (see model)

Habitat variable scores can be used to calculate life requisite (water and food) values by cover type using the equations provided in the model.

Ecological and environmental benefits

Beavers occupy complex roles in their interrelationships with habitat, wildlife, and humans. The beneficial and detrimental impacts are often a reflection of the human perception of how these interrelationships affect his interests.

Wetlands created by beavers are beneficial to soil conservation, water resources, ground water discharge, water quality improvement, consumptive and non-consumptive outdoor experiences, aesthetic beauty, and habitat creation for native wildlife, fish, and plant species. Conversely, beaver activities have led to significant timber, agricultural, infrastructural, and homeowner damage. Beaver wetlands are important to humans and their environment.

Soils

The value of the beaver's contribution toward protecting and conserving soils is poorly understood and may never be fully appreciated (Hill 1982). Beaver ponds serve as basins for the entrapment of streambed silt and eroding soil. Sediment particles fall out of the water column and settle on the pond bottom as a result of decreased stream velocity. Aquatic and early successional plants become established in the newly-deposited sediment. Conditions then become favorable for flood plain stabilization by more permanent woody vegetation. During flood conditions, beaver wetlands slow and effectively decrease floodwater scour, preventing washing of sediment downstream (Arner and Jones 2009).

Water

Beaver impoundments effectively trap and store water. If numerous dams are well-distributed, they have the effect of holding most precipitation near where it falls or melts and fill the soil to saturation (Hill 1982). The water is then released gradually by downhill gravitational pull and laterally through underground seepage. Eventually, the water finds its way to feeder streams and larger streams. Beaver pond complexes act as sponges, absorbing water during wet periods and releasing it slowly during dry periods (Arner and Jones 2009). This regulated water flow is valuable as protection from flood damage and as a water source during drought conditions.

Acid mine streams benefit from beaver impoundments. In acid mine watersheds, beaver ponds provide some degree of purification through water pooling. Beaver ponds also provide the essentials for early plant succession within degraded watersheds (Hill 1982).

Organic materials such as leaves, branches, and other plant structures accumulate within the increased surface area of the beaver pond, providing forage and cover for aquatic invertebrates. Naiman et al. (1986) reported 2,000-6,500 m^3 of sediment retained by a dam ranging 4-18 m^3 in volume. In Quebec, Naiman and Melillo (1984) observed a 1,000-fold increase in nitrogen after beavers impounded a stream. They also observed a reduction in nitrogen from outside the system and an increase in nitrogen fixation. Beaver impoundments increase carbon inputs, methane fluxes, and hydrogen sulfide emissions (Johnston and Naiman 1987). As a result, the ecosystem efficiency for the utilization and storage of organic inputs (stream metabolism index) increases (Naiman et al. 1988).

The aquatic invertebrate community structure is changed when a beaver impoundment is created. Running-water invertebrate taxa are replaced by pond taxa, primarily in response to finer sediments and a decrease in current speed (Naiman et al. 1988). Beaver ponds also influence community function by increasing the absolute importance of invertebrate collectors and predators, while decreasing the relative importance of invertebrate shredders and scrapers (McDowell and Naiman 1986). Total density and biomass in ponds may be 2-5 times greater than those of running water sites, ranging from 11,000-73,000 organisms/m^2 and from 1-11 g/m^2, depending upon the season (Naiman et al. 1988).

Fish

Beaver impoundments are generally beneficial to fish. Ponds created by beavers provide conditions favorable for higher plankton and other micro-organism production that serve as rearing units for small fish and deep water for protection during the winter (Denney 1952). In areas of extremely cold waters, beaver ponds are beneficial to trout fisheries, but are harmful where water temperatures become excessively warmed (Knudsen 1962).

Wildlife

Highly-productive wetland habitats created by beavers have been shown to benefit a wide variety of wildlife species including waterfowl (Beard 1953; Renouf 1972; Hepp and Hair 1977; Ringelman 1991), a broad range of other avian species (Reese and Hair 1976, Prosser 1998), and aquatic furbearers (Dubuc et al. 1990). The major benefit of beaver wetlands is the creation of standing water, edge, and plant diversity, all within close proximity to one another (Hill 1982). Habitat types supporting beavers are extremely diverse. However, the actual habitat created by beavers is often very similar. Without beavers, many areas would be less attractive to other wildlife.

Many avian species benefit from some stage of beaver activity (Reese and Hair 1976). Active beaver ponds provide valuable nesting, feeding, and migratory habitat for waterfowl (Beard 1953, Renouf 1972, Grover and Baldasarre 1995). Wetland-dependent songbirds may use various stages of beaver ponds depending on their foraging and nesting requirements. Thus, management of beaver ponds should consider effects on multiple avian groups.

Ecosystem

Beaver ponds and beaver browsing affect soil fertility, water chemistry, plant succession, and the rate of plant growth (Wilde et al. 1950). Environmental conditions surrounding active beaver ponds are constantly changing. These shifting conditions are dependent upon pond age and size, successional status, substrate, hydrologic characteristics, and resource inputs and have both special and temporal components (Naiman et al. 1988). Since all beaver ponds along a stream are not identical habitat, ecosystem parameters do not remain spatially constant. Naiman et al. (1988) used the example of one pond that may be predominantly a bog (due to local hydrology and topography) with one rate of primary production and another pond that may be an emergent marsh with a different rate of production. The connecting stream riffle may have completely different primary productivity.

Active beaver ponds will progress through natural plant succession over time. As beaver numbers and food supplies change, there will be temporal shifts in the density and diversity of beaver habitats. Beaver pond succession occurs over a period of about 20-30 years, starting from dam construction on a forested stream, to the increase in open water and loss of wooded cover, and to the eventual invasion of emergent vegetative species (Naimen et al. 1988). Within this timeframe, beaver pond succession appears to be unidirectional and fairly predictive. Once beavers abandon a pond, succession becomes highly unpredictable, depending on multiple factors including topography, hydrology, soil structure and composition, and vegetative community assemblages (Naimen et al. 1988). Mud flats quickly become dense mats of sedges (Carex spp.) and grasses. These beaver meadows prevent soil erosion, but are short-lived in coarse, sandy soils (Wilde et al. 1950). However, in peat or muck soils, humic acid in the sedimentation inhibits decay and prolongs plant succession (Ives 1942).

In Pennsylvania, Prosser (1998) defined four stages of beaver pond succession based on beaver activity and initial conditions. Her beaver pond successional stages were new-forested, new-open, old-active, and abandoned. She found that, in general, more plant food resources for birds were present in older beaver ponds (old-active and abandoned) than in new-forested ponds. Higher plant abundance also appeared as a trend in the older successional stages. Animal food resources were present in most successional stages. The natural multi-successional composition of beaver ponds in Pennsylvania offer nesting and brood-rearing habitat for an array of wetland-dependent avian species. She noted that management of beavers should not be attempted without considering the effects to all species. Overall, new-forested and old-active ponds were used most frequently by waterfowl adults and broods, whereas old-active and abandoned ponds provided habitat for less common species such as the American bittern (*Botaurus lentiginosus)* and Virginia rail (*Rallus limicola*).

Forage management

Managing the food supply of beavers is possible in some cases. Prescribed burning has been effectively used to encourage aspen growth in mixed conifer habitat (Baker and Hill 2003). Many forage species are available to beavers throughout their entire Pennsylvania range. Management of a single food species is generally not practical where many other food options are available. Small-scale habitat improvements at a local level may be justifiable.

SECTION 3: MANAGEMENT HISTORY

Historical events

Native Americans as well as many European and Asian hunting tribes maintained high regard for beavers. The Crow Indian tribe believed in the reincarnation of man into the form of a beaver (Allred 1986). Therefore, the beaver deserved special respect, since any beaver could be a deceased relative or friend. The Cherokees believed it was the beaver which created the continents by dredging them up from the primeval seas. Thus, they recognized the beaver as a great engineer. Asian tribes developed a form of social life called "beaver economy" by some Russians (Wilsson 1968).

Almost every part of a beaver's body was used by Native Americans Wilsson (1968). The flesh was considered a delicacy and the fat was used as a treatment for frostbite. Castoreum was considered an effective cure for practically every physical ailment. The skin was used to make clothes, rugs, moccasins, stockings, rope, and many other items. The dead were wrapped in beaver skins. To give a skin to anyone as a present was a sign of special friendship. Native Americans regarded the beaver as a holy animal, often entering into their religious legends. For centuries, various tribes and families had their own beaver grounds and preserved a well-calculated balance between beaver populations and man.

The first economic interest in beavers by Europeans and Asians was based on its medicinal importance (Wilsson 1968). The fur was always highly valued, but the insatiable demand for castoreum sparked increased beaver taking. Unlike Native American cultures, western civilization commonly believed that nature provided a never-ending source of goods.

By the 1600s, the top hat became a symbol of distinction in the royal courts of Europe. Top hats were made of felt produced from wool or fur. The finest felt was made of beaver fur. In 1638, King Charles I of England was rumored to have said "nothing but beaver stuff or beaver wool shall be used in the making of hats (Allred 1986)." Because the beaver hat was a status symbol in Europe, the supply of European beavers was quickly exhausted. The species suffered near-extinction with a few remnant populations surviving in southern Norway and small portions of Germany, France, Poland, and Russia (Wilsson 1968). The world market then turned to North America to supply beaver skins and castoreum.

Based on records compiled by Wilsson (1968), organized attempts to establish a fur trade between Europe and North America began in the early 1600s. Stations for handling beaver pelts were established in French Canada, including one at Quebec in 1604 and another at Montreal in 1611. The Montreal station developed rapidly and became a main trading center. An event that significantly advanced the fur trade occurred in 1670 when the Hudson's Bay Company, founded by the British, acquired control over large areas of land in exchange for exploration of the Northwest Passage. When the governor of French Canada tried to take over the Hudson's Bay Company, competition between the English and the French led to open war.

After peace was restored, the fur trade expanded rapidly and lasted for decades. Most trading stations could supply 20,000 beaver skins per year. Beaver skins represented about two thirds of total export value of all goods. Beaver pelts became a medium of exchange. Exchange rate in trade was based upon a blanket-sized beaver. A large beaver bought 1/10 of a gun; ½ pound of gun powder; 2 lbs. of shot; ½ lb. beads; one hatchet; or 1/12 of a wool blanket (Allred 1986).

In the mid-1700s, the Hudson's Bay Company was exporting more than 200,000 beaver skins per year to Europe. An estimated 500,000 beavers were taken annually in North America during peak demand (Wilsson 1968). Most skins were sold at auctions in London to hat makers. Beaver hats were extremely popular during that period. By the end of the 1800s, beavers had been extirpated over most of the continent.

Beaver felt hats were very popular and important to European men's fashion for more than 300 years. Selling beaver pelts to Europe was New York City's first business (Sterba 2002). Beavers were so important to the economy of New York City that two beavers appear on the city's official seal. Similarly, the beaver is a national symbol of Canada and a key influential force in shaping the history of North America.

Rhoads (1903) compiled rare historical and descriptive accounts in a book of mammal distribution and status in Pennsylvania and New Jersey. At the beginning of the 1900s, Rhoads found no evidence of the existence of beavers in Pennsylvania or New Jersey. He noted that beavers were once very numerous in the higher mountain lakes and headwaters of the Allegheny and Susquehanna Rivers. However, beavers were nearly extirpated by 1830 in the northeastern portion of Pennsylvania and that some remained in the headwaters of the west branch of the Susquehanna River until about 1840. The last few beavers known to naturally exist in Pennsylvania were killed in Elk, Cameron, and Centre counties between 1850 and 1865. For the next 35 years, only two beavers were documented in the Commonwealth according to Rhoads. One was killed in Clinton County in 1884 and the other was sighted in Cambria County in 1884. It is possible that these beavers were imported from another part of the country and subsequently escaped or were released.

In 1903, a law was passed by the Pennsylvania legislature prohibiting the capture or killing of beavers (Anonymous 1942). The fine for this offense was $100. There are no records of any beavers occurring in Pennsylvania during 1902-1915. Beavers were considered completely extirpated from the Commonwealth during that period.

Efforts to restore beavers to Pennsylvania and many other eastern states began in the early 1900s. Continent-wide restoration programs took place during the 1950s (Hill 1982). In Pennsylvania, restoration efforts began in 1917 with the release of one pair of beavers from Wisconsin. Subsequent releases of 100 beavers occurred during 1918-1925 (Pennsylvania Game Commission Data Book, unpublished report). Restoration efforts were extremely successful, with substantial growth recorded during the 1920s and 30s. Due to widespread damage complaints, a regulated beaver harvest was initiated in 1934. Intensive beaver harvest management and strict regulation were employed to safeguard this wildlife resource from any future threat of extirpation (Kosack 1995).

Harvest

The first regulated harvest of beavers in 1934 was the start of a lasting tradition for many trappers. The historical rebirth of this activity and the restoration of beaver populations were huge wildlife management success stories for Pennsylvania. As beaver populations grew, trappers quickly realized the economic and social benefits of beaver trapping. A regulated harvest is not only important in sustaining a healthy beaver population, but also minimizing conflicts with humans.

Attempting to achieve the goals of fair chase, equal/ample opportunity, and rewarding trapping experience, along with reducing the risk for repeated extirpation, regulations were established and modified as beaver populations changed in number and in distribution across Pennsylvania. The first regulations included a 6-beaver limit per trapper, a 10-trap limit, and mandatory tagging of all beavers harvested.

Since the start of Pennsylvania's regulated beaver trapping in 1934, many of the strict beaver trapping regulations imposed decades ago are still enforced today. These restrictions included a limit on numbers of body-gripping traps allowed for use, trap placement prohibition near lodges and dams, a limit on total numbers of beaver traps allowed, a specific bag limit, and a moderately conservative season length. The purpose of these restrictions was to prevent over harvest and provide greater opportunity for more trappers to be successful. Although some details of beaver regulation changes have been lost, a summary of regulations from 1934 to the present is compiled in Appendix 1.

Mandatory beaver pelt tagging was used to determine the total annual harvest and practiced in Pennsylvania from 1934 to 2000. Successful trappers were required to have each pelt tagged by a Wildlife Conservation Officer and pay a fee of 50 cents for each tag needed. This activity provided an accurate harvest inventory as well as an opportunity for trappers and Game Commission personnel to interact. The practice allowed collection of pelt size and weight data as well as information on county and township of capture.

After the 1934 opening of the beaver season produced a substantial harvest, the 1935 season was closed. A beaver harvest season has been allowed each year since 1935. As beaver populations became more secure, there appeared to be little need to obtain an exact count of the beaver harvest. As harvest totals increased, the practice of beaver tagging became burdensome to both the trapper and Game Commission personnel. The need for pelt sealing was also being questioned by other state and provincial agencies (Peterson 2000). Beginning in 2004, the beaver tagging requirement was discontinued. Furtaker mail survey results were then used to estimate harvest. The furtaker survey was not conducted in 2004 and the harvest was not estimated during that year.

The beaver harvest in Pennsylvania is summarized in Figure 5. Mandatory pelt tagging records were used to determine the harvest during 1934-2002. Harvest data from 1942-1957 are missing from our records. The harvest was not estimated in 2004. However, beginning in 2003 and 2005-present, the beaver harvest was estimated from the annual furtaker survey. Each year, harvest questionnaires were mailed to a random sample of licensed furtakers. In 2008, harvest surveys were mailed to 4,562 of 26,583 (17%) licensed furtakers (Boyd and Cegelski 2008). Three thousand three hundred ninety (74%) of surveyed furtakers responded. Based on these data, the beaver harvest was estimated.

At the start of regulated beaver trapping in Pennsylvania, beaver populations may have sharply decreased after the first open season in 1934, then increased (Fig. 5). As noted by Novak (1987) in reference to Ontario's beaver harvest (Fig. 4), a smooth harvest line is typical during decreasing and increasing population phases. During the period 1958-present, Pennsylvania beaver populations were likely stable or gradually increasing. The plotted harvest line was saw-toothed (Fig. 5) during this period, reflecting variable economic and weather conditions that influenced the ability or desire of trappers to harvest beavers.

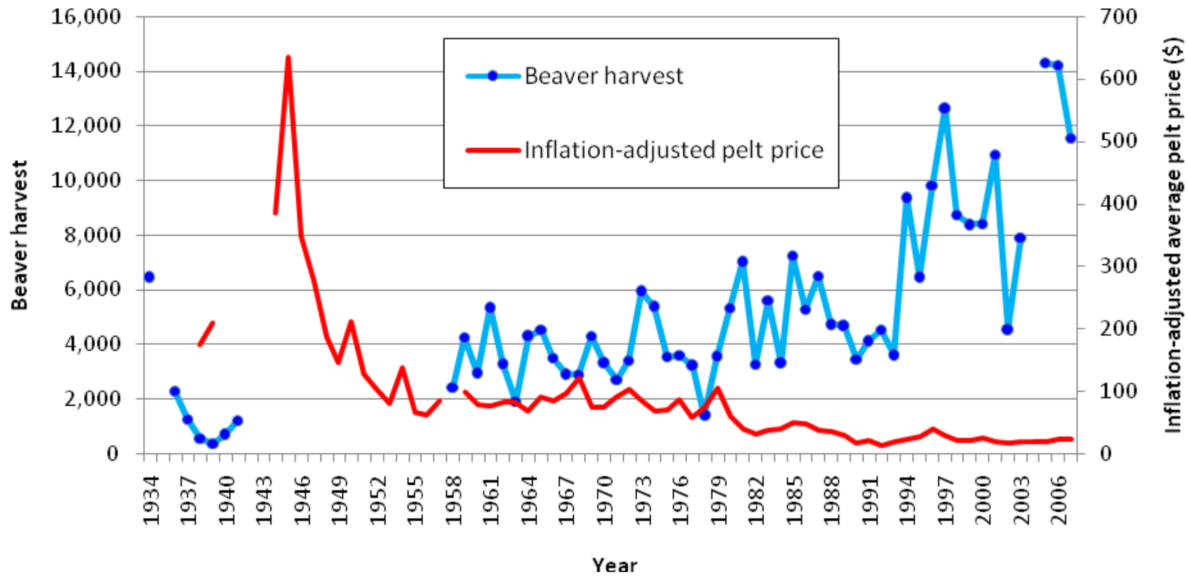


Figure 5. Pennsylvania beaver harvest based on mandatory tagging (1934-2002) and mail survey estimates (2003, 2005-2007) and 2008 inflation-adjusted average pelt prices paid during 1938-2007. The beaver season was closed in 1935 and harvest data for 1942-1957 are missing. The harvest was not estimated in 2004.

Past management practices

Few details of beaver population management during 1934-1988 exist, other than harvest data collection and slight changes in season length and bag limits to address nuisance problems. Beginning in 1989, beaver population management consisted of three major components: preseason population estimation, harvest goal setting, and harvest determination. Season length was adjusted to attain the harvest level necessary to achieve the desired goals. An accurate record of the beaver harvest was needed to gauge the success or failure of the season length adjustment. The New York Department of Environmental Conservation's beaver management plan (Bishop et. al 1992) was used as a basis for the management model during 1989-1998.

Six furbearer management areas based on physiographic and ecological features were established within Pennsylvania from 1991-2002 (Appendix 2). Each management area had similar beaver habitat and harvest levels. Defined management areas enabled us to establish appropriate beaver trapping regulations for each area and more effectively manage the harvest.

Past beaver population monitoring consisted of field surveys to determine presence or absence of active beaver colonies based on sign and beaver structures. In furbearer management areas 1, 2, 3, and 4, sampling was used to assess beaver populations. A total count of beaver colonies was made in furbearer management areas 5 and 6.

A stratified random sample of topographic quadrangle maps was chosen covering 15% of furbearer management areas 1, 2, 3, and 4. Each map was divided into one-quarter sections. A 3.2 x 4.8 km^2 (2 x 3 mi^2) rectangle was centered in each quarter quadrangle and outlined as the survey plot. Wildlife officers surveyed each plot and recorded all active and inactive beaver colonies found in the sampled 2 x 3 mi^2 plots. Active beaver habitats were defined as any habitat that had current activity (cutting, dam building, or food cache) due to the presence of one or more beavers. An inactive beaver habitat was described as any habitat that had no current activity but showed sign of past beaver activity.

Survey plots were stratified into high or low beaver harvest categories. The high or low category was based upon the beaver harvest per square mile within the township for the 2 previous years and determined by comparing this local harvest rate to the mean harvest rate for the entire management area. Local harvest rates greater than the mean were considered high beaver harvest plots. Rates lower than or equal to the mean were considered low beaver harvest plots.

An average number of active beaver colonies in the high and low harvest plots was calculated. These averages were then applied to the total square mile areas of the high and low plots in the management area to determine the number of beaver colonies present in the management area. We calculated a beaver population estimate by assuming 6.2 beavers lived in each active beaver colony or habitat within each management area. Brenner's (1964) work in Crawford County, Pennsylvania was the basis for the 6.2 beaver-per-colony average. No attempt was made to validate Brenner's (1964) mean beaver colony size elsewhere in Pennsylvania.

Harvest goals for each management area were calculated based on percent of beaver occupancy and number of beavers to be removed per active habitat. Beaver occupancy was defined as the number of active habitats per total habitats surveyed and was expressed as a percentage (%). To maintain optimum habitat conditions for beaver, waterfowl, and other wildlife, we set our statewide occupancy goal at 25%. Novak (pers. comm.) suggested that a harvest of 1 beaver per active colony would allow the population to increase, 1.5 beaver per colony would stabilize the population, 2 per colony will decrease the population, and 2.5 would reduce the population rapidly. We used these guidelines to estimate removal rates needed to achieve our harvest and population goals.

Packets of maps and census forms were mailed annually to all WCOs in early September. Officers completed all beaver surveys by January. We resurveyed 5 randomly selected maps from high and low harvest areas within in each management area to determine accuracy of

Wildlife Officer field surveys. Errors were common and variability high. We developed correction factors for each furbearer management area by resurveying areas previously field-checked. Correction factors were necessary during each of the 14 years field surveys occurred.

In management areas where the regular season (December-January) beaver harvest was <70% of the goal, the season was extended for one month during March. In areas where the harvest exceeded 70% of the goal or met goal, the season did not reopen that year. Trends in beaver population estimates and harvests during the 14-year monitoring period are depicted in Figure 6. Harvest goals and season extensions, if needed, appeared to regulate the harvest at desired levels. However, the season structure did not allow harvest during February, a month of greatest pelt primeness.

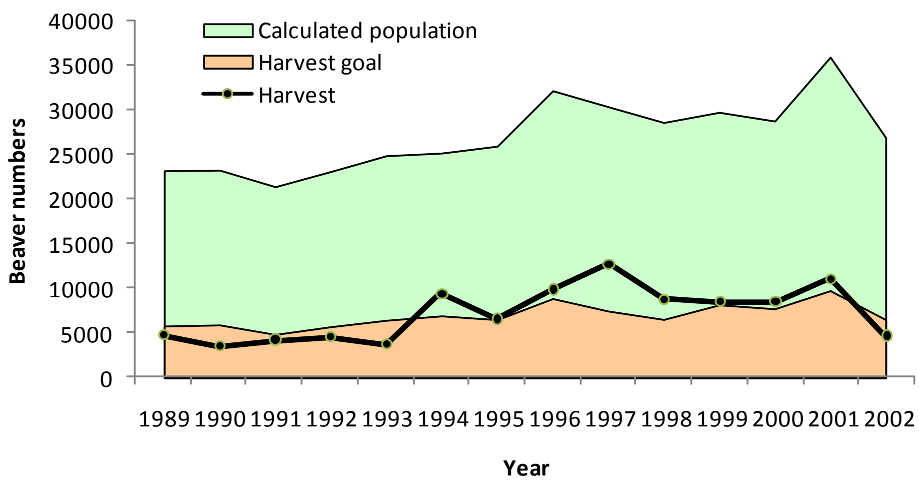


Figure 6. Pennsylvania statewide beaver harvest and management goals during 1989-2002.

The age structure of the statewide beaver harvest was also monitored during 1990-2002. Body weight and pelt measurement data from tagged beavers were collected by WCOs as part of the mandatory beaver pelt sealing process. WCOs were instructed to differentiate estimated weights from actual weights. Estimated weights of beavers over 27 lbs (12.2 kg) were not used to determine age class. We found that trappers often make substantial errors in estimating beaver weights, especially on adult-sized beavers.

We used age criteria developed by Hayden (1990) to differentiate beaver age classes. Juveniles were classified as having body weights <28 lbs (12.7 kg) and pelt measurements of <54 inches (137 cm). Beavers with weights between 29 and 40 lbs (13-18 kg) or with pelt size of 59-66 inches (150-168 cm) were considered subadults. Adults were defined as having weights >40 lbs (18 kg) and pelt size of >68 inches (173 cm). Pelts are measured by totaling the length and width.

Over the 13-year monitoring period, the proportion of adult, subadult, and kit age classes of harvested beavers remained stable (Fig. 7). Adults comprised 11-20% of the harvest. Because of their greater activity away from the lodge or den site, adults are more susceptible to winter trapping than kits or yearlings (Payne 1975). However, trapping near beaver structures, such as lodges and dams, generally results in a larger harvest of subadults and kits. Subadults made up 30-42% of the harvest, while kits comprised 44-53% of the annual take. By definition, subadults are the size of adults, but are not sexually mature. Some beavers classified as subadults based on pelt size or body weight may have been sexually mature. Nonetheless, 80-89% of harvested beavers were considered not of breeding age. This was a huge proportion of harvest. Beaver

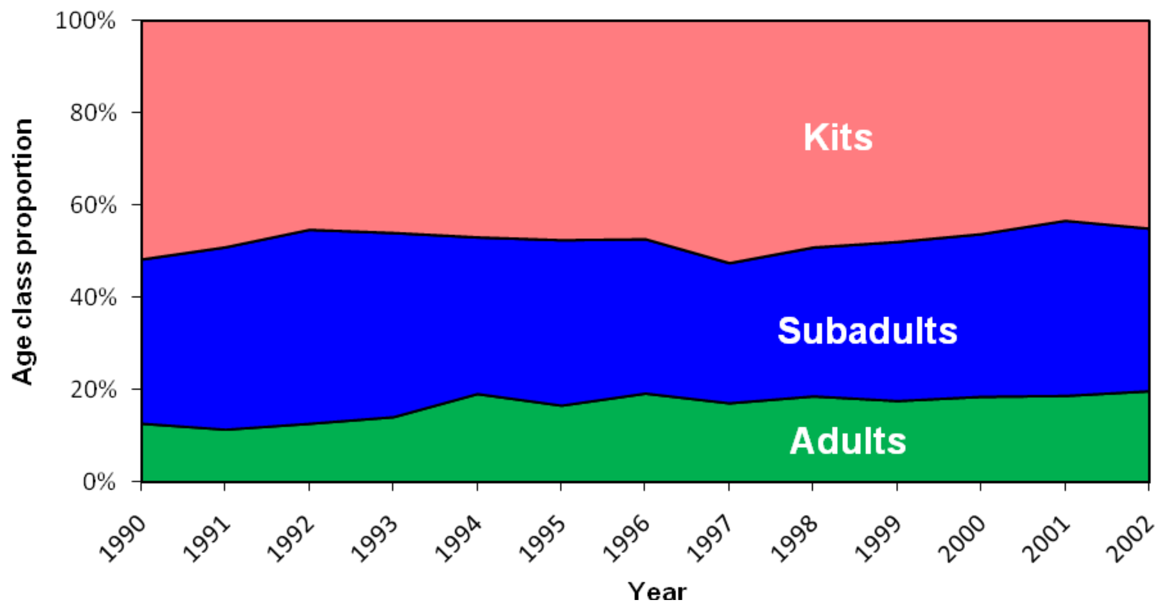


Figure 7. Age structure of trapped beavers in Pennsylvania during 1990-2002.

populations appeared to be stable or slightly increasing during this period (Fig. 6).

Beaver management during 1989-2002 established furbearer management areas, annual surveys for active and inactive colonies, pelt tagging and age data collection requirements, damage complaint inventories, and population size and harvest goal estimates for each furbearer management area. A season extension was implemented only once in 1995. Since beaver populations across most of Pennsylvania appeared secure by 2002, established strategies for managing this fur resource were discontinued. Furbearer management areas were replaced by wildlife management units in 2003. Beaver pelt tagging, body size data collection, field surveys, populations size estimates, and harvest goals establishment ended by 2004.

SECTION 4: DAMAGE MANAGEMENT

Habitat modification by beavers is often very beneficial to many forms of wildlife. However, when beaver habitat changes conflict with human objectives, the damage impact usually outweighs any habitat benefits (Miller and Yarrow 1994). Beaver damage can be severe and costly. As human populations expand into more rural areas, nuisance beaver conflicts will likely increase in Pennsylvania. Human tolerance of beaver problems is partially dependent upon the type and severity of damage and partially upon an individual's level of wildlife appreciation. The lack of knowledge and expertise of many urban and suburban landowners to understand and sometimes solve nuisance animal problems on their own increases the likelihood of damage complaints (Flyger et al. 1983). Killing individual problem beavers and controlled harvests of beaver populations are often the most effective means of damage control. However, lethal methods of dealing with nuisance animals can generate controversy among landowners who appreciate and attempt to attract wildlife (San Julian 1983).

Damage types

The most common types of beaver nuisance complaints include flooding, burrowing, gnawing, damming, and health damages. Southwick Associates (1994) surveyed 42 states and 6 Canadian provinces to assess the status of beaver damage and management issues. They found that flooding damage was the most severe and of most concern to wildlife agencies and the public throughout the United States and Canada.

As part of the 1995 Wildlife Conservation Officer furbearer questionnaire, we asked what types of beaver damage complaints were reported by Pennsylvania landowners. Flooding-related damage comprised 60% of all beaver complaints recorded by WCOs in 1995 (Table 2). A plugged culvert was the most common beaver damage complaint. Invasion of farm ponds and urban or suburban areas totaled 15%. Beavers also commonly cut ornamental and shade trees near streams and lake shores. This damage type made up 12% of landowner complaints.

Table 2. Pennsylvania beaver complaint frequency and type reported to Wildlife Conservation Officers in 1995.

Beaver complaint type	No. of complaints (%)
Plugged culvert	245 (27.6)
Flooded road	145 (16.3)
Cutting trees	109 (12.3)
Flooded field	106 (11.9)
Invaded farm pond	84 (9.5)
Do not like	64 (7.2)
Flooded woodland	41 (4.6)
Invaded housing project lake	31 (3.5)
Giardia problem	18 (2.0)
Invaded urban area	17 (1.9)
Other	28 (3.2)
Total:	888 (100.0)

By far, the flooding effects of beaver-created blockages in or around streams, ditches, culverts, drainage pipes, bridges, and other waterway structures constitute the most common and costly damage. Miller and Yarrow (1994) noted that some road ditches, culverts, and drainage pipes have been obstructed so heavily by beavers that explosives were needed to remove the compacted debris. The structures had to be replaced. They also reported that some bridges had to be destroyed because of beaver dam construction.

In agricultural areas, pastures and row-crop fields adjacent to stream or drainages containing woody riparian buffers are sometimes flooded by beaver dams. Cornfields planted near rivers, large streams, wetlands, and lakes are susceptible to damage from beavers. Beaver damage usually coincides with ear development on the stalk and may continue through harvest. Clean angular cut stalks are conclusive for beaver damage (Anonymous 2001). Beaver will often drag the stalk to their lodge, near water, or adjacent to some other kind of cover before they begin to feed.

Timber damage by beavers can be significant. Flooding caused by beaver dam construction can be significant in areas of flat terrain along stream bottoms. If root systems remain inundated for more than one growing season, a proportionally larger number of trees will die (Hill 1982). Beavers frequently gnaw bark from large hardwoods and do not fell the tree. Bite wounds may only occur on a portion of the trunk, but still subject the tree to disease and subsequent rot.

Damage to trout fisheries can be serious where low-gradient streams or marginal trout habitat exist. Harmful effects of beaver ponds on trout include elevated water temperature on shallow, slow-moving streams reducing available oxygen, destruction of spawning areas and eggs from siltation, reduction in some species of aquatic insects fed on by trout, and barriers to trout movement created by beaver dams (Denny 1952, Hakala 1952).

Less common complaints are sometimes the most costly. Reservoir dams and levees are occasionally selected by beaver for den sites. Significant burrowing often occurs. Repair costs can be substantial. Continued flooding and burrowing has even caused train derailments (Miller and Yarrow 1994). Beavers occasionally feed on garden vegetables, wander through residential properties, and flood septic systems. They have also been blamed for contaminating public drinking water with the intestinal parasite *Giardia lamblia* (Miller 1983). Although, it is highly unlikely that beavers are the cause of drinking water contamination (Woo and Paterson 1986 cited in de Almeida 1987).

Economic impact

In the early 1980s, the annual cost of beaver damage in the United States was $75-100 million (Miller 1983). Over a 40-year period in the southeastern U.S., Arner and Dubose (1982) estimated total economic loss caused by beavers at $4 billion. In New York during 1993, property damage was estimated at $5.5 million at 2,113 sites (New York State Department of Environmental Conservation 1996). Plus, an additional $330,000 was spent to handle the complaints. No dollar estimate of beaver damage has been compiled for Pennsylvania. However, damage complaints reported to Pennsylvania field officers averaged 688 during the past 12 years (Fig. 8). In 1996, 1,140 complaints were documented within the Commonwealth. Considering this quantity of damage reports, property damage probably exceeds $1 million annually.

Damage monitoring

We annually monitor beaver damage complaints from Wildlife Conservation Officer records. A furbearer questionnaire (Appendix 3) has been distributed nearly every year since 1995. Officers are asked to report the number of beaver nuisance complaints within their districts. A decreasing linear trend in the number of beaver complaints occurred during 1995-2008 (Fig. 8). It is unclear whether this trend reflects population declines, greater landowner tolerance of beaver damage, or decreased damage reporting.

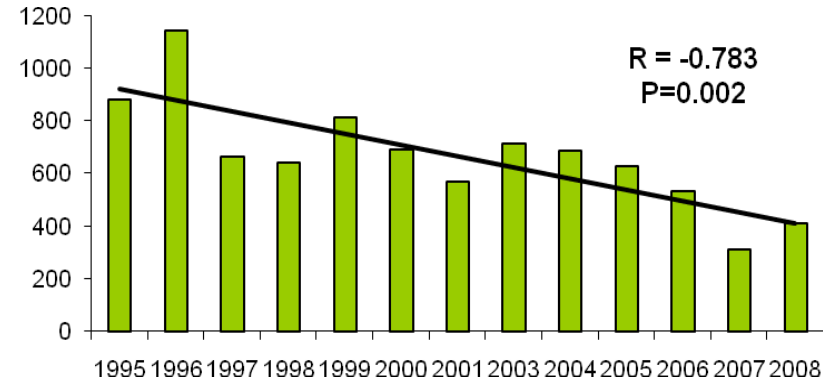


Figure 8. Trend in the number of beaver complaints reported annually to Widlife Conservation Officers during 1995-2008.

In 2008, beaver complaints were not equally distributed throughout Pennsylvania (Fig. 9). Based on the 2008 WCO furbearer survey (Appendix 3), field officers received more complaints in the northern half of the state, especially in the northwestern and northeastern portions than in other areas. These are areas of traditionally high beaver densities and, consequently, generate greater landowner conflict.

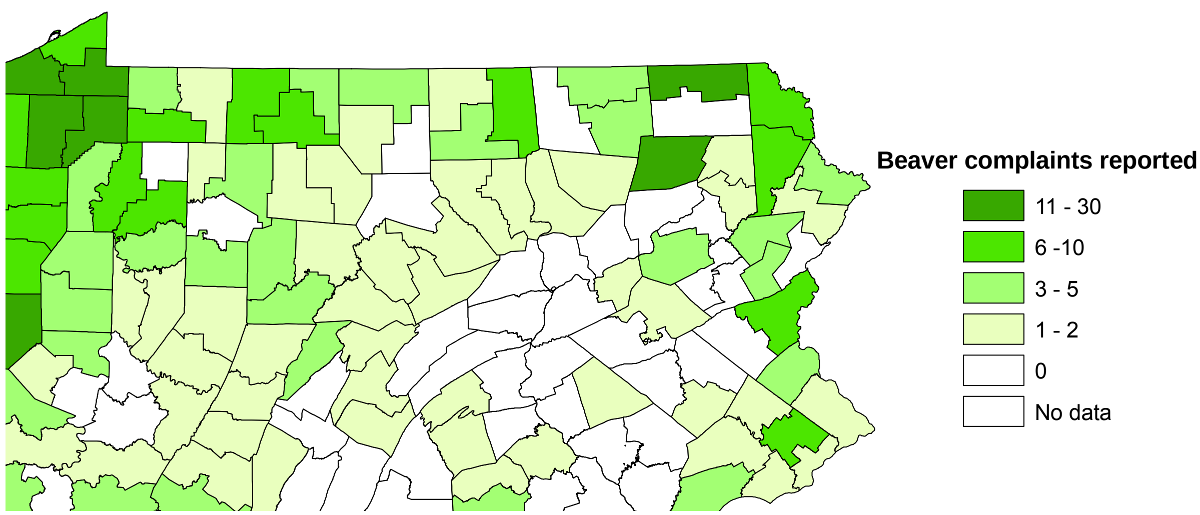


Fig. 9. Distribution and frequency of beaver complaints reported by Wildlife Conservation Officers during 2008.

Damage control

An annual regulated beaver harvest may be the most practical and prudent approach to controlling damage problems. Populations are reduced by citizen participation at no expense to the public (Hill 1976). The most commonly used beaver control methods in the U.S. and Canada include trapping (100%), dam removal (90%), shooting (84%), water flow device installation (84%), snaring (76%), and relocation (59%) (Southwick Associates 1994).

Exclusion and preventive measures

Fencing out beavers from individual trees, ponds, or lakes is costly, but is an effective preventive measure. Trees near waterways may be protected by enclosing the bottom 3 ft (1 m) of each tree trunk with heavy woven wire mesh, hardware cloth, or sheet metal (Miller and Yarrow 1994). Fencing large areas is usually very expensive and not practical. Erecting a fence around culverts, drainpipes, and water control devices can sometimes prevent damage, but can also promote damage. Beavers may use fencing as material for dam building (Miller and Yarrow 1994).

Several practices have shown some promise in preventing damage. Eliminating food sources such as trees and woody vegetation near beaver habitat may discourage beaver use of an area. Miller and Yarrow (1994) found that daily destruction of dams and removal of dam construction material may cause a colony or individual beaver to move to another site. Dam removal using explosives after beaver numbers are reduced within an impoundment is also effective.

When properly installed, a 3-log drain (Arner 1963) or other structural device to control beaver pond water levels will prevent flood damage and occasionally cause beavers to move to another area. If beavers do not move from the area, these structures prevent beavers from controlling water levels as long as they do not become plugged with mud and debris. If beavers can detect the sound of running water or current flow near the water control device, they will quickly and instinctively plug the source of water drainage (Wilsson 1971). All water control devices installed in beaver dams should be constructed in such a way that water intake occurs without noticeable current flow or running water sound. Behavior patterns of beavers must be considered when designing or installing any water level control device.

Capture and removal methods

Regulated trapping is probably the most effective method of permanently removing nuisance beavers from an area. Four basic trap types are used for beavers including foothold traps, cage traps, body-gripping traps, and cable devices. When correct sizes and types are used properly, these trapping devices meet best management practices (BMP) criteria for beavers in the United States (Association of Fish and Wildlife Agencies 2007*a*). The purpose of the BMP program was to scientifically evaluate traps and trapping systems used for capturing furbearers in the United States (Association of Fish and Wildlife Agencies 2007*b*). BMP research provided guidance to trappers in selecting and using trapping devices meeting international animal welfare standards. Through extensive research and field-testing, BMP work also provided information to help trappers increase trap efficiency, selectivity, practicality, and safety.

Foothold and body-gripping traps are the most common devices used to trap beavers. When used in submersion sets only, foothold traps of sizes commonly designated in 2009 equipment catalogs as number 11, 1.5, 1.65, 1.75, 2, 3, 4, and 5 fulfilled BMP requirements. Body-gripping trap sizes commonly designated as 220, 280, 330, and 440 also passed BMP evaluation. Numeric foothold and body-gripping trap sizes are not standardized and may vary by manufacturer. Beaver trapping techniques using foothold and body-gripping traps are described in great detail by Baker and Dwyer (1987) and Miller and Yarrow (1994). In Alabama, Hill (1976) found that 2-3 body-gripping traps set for about 2 weeks in a colony during each of two years effectively eliminated beavers.

Suitcase-type cage traps may be used in locations and in weather conditions where other traps are less effective. Hancock and Bailey cage traps met BMP criteria for beavers in the United States (Association of Fish and Wildlife Agencies 2007*a*). These traps are large, cumbersome, and expensive, but hold animals alive and allow for release. Apples and corn are effective baits when making sets with this trap type (de Almeida 1987).

Using cable devices (cable restraints and snares) can be a very cost-effective method of capturing beavers. Snaring equipment costs much less than conventional trapping equipment and can be easier to use in many situations (Miller and Yarrow 1994). Not all cable device configurations are suitable for live restraint. Devices with small cable diameter and non-relaxing locks should only be used in submersion or under-ice sets. The Association of Fish and Wildlife Agencies (2007*a*) established cable device guidelines for beaver that meet BMP testing criteria. Techniques for snaring beavers are described in Weaver et al. (1985) and Baker and Dwyer (1987). Where live capture is desired, cable restraints are preferable to cage traps because they can be more easily and safely carried, handled, and set (Hill 1982). If a nuisance beaver area can be saturated with snares and/or restraint devices, the catch per unit effort and expense will often match that of other capture methods.

A variety of other control methods have been attempted to remove or decrease beaver populations. Shooting can be an effective beaver control method where firearms can be used safely. In situations where beavers have become significant pests, night hunting using spotlights and motor boats has been productive (Hill 1982). Gordon and Arner (1976) used orally-administered chemosterilants to attempt to reduce fecundity of beavers. The controlled experiments used two types of estrogen compounds and resulted in suppressed spermatogenesis in treated males and reduced ovulation in females. Effective methods of treating beavers with chemosterilants in the wild were not established. Brooks et al. (1980) found that sterilization was effective in reducing fecundity in Massachusetts beavers. However, behavior and family integrity were altered producing undesirable results. Trained, mixed-breed dogs have been used in Alabama to aid in removing beavers from drained pond complexes (Hill 1982). After dams were removed by hand or with explosives, the trained dogs were very effective at flushing beavers out of lodges and exposed bank dens. Beavers could be caught alive or shot.

In urban settings, beavers passing through yards or swimming near houses will generally leave on their own. They can be chased into the nearest drainage ditch or waterway, if necessary. De Almeida (1987) noted that beavers can be caught by chasing them into an open area and covering them with a garbage can. The lid is slid underneath and the can inverted. The beaver then can be relocated away from the area, if desired.

SECTION 5: RESOURCE AND ECONOMIC VALUES

The value of regulated beaver trapping is difficult to quantify. For most trappers, there is no single motive driving their participation. Recreation, challenge, outdoor experience, and similarly-phrased reasons are identified as primary motivators (Bailey 1981, Boddicker 1981, Marshall 1981, Samuel and Bammel 1981). Income from trapping is less important to trappers, but fur values profoundly affect trapper numbers, trapping effort, and harvest for most furbearer species (Erickson and Sampson 1978, Erickson 1981).

Beaver trapping provides income and an outdoor lifestyle for many Pennsylvania residents. A strong interest in beaver trapping has persisted since the first regulated trapping season in 1934. Today, beaver trapping remains a very popular activity in Pennsylvania. Hill (1982) described the benefits of beaver trapping as unique opportunities to experience tending a trapline, processing fur, reading animal tracks and sign, and learning and teaching woodsmanship. The habitat created by beavers also provides suitable conditions for waterfowl hunting and other furbearer trapping. Hill (1982) noted that some people removed from rural environments often do not understand relationships among wild animals and their habitats. These people may not accept consumptive use of any animal in a way that causes its death. However, most people that have lived in close association with rural settings look at furbearer populations and their perpetual existence, rather than the fate of each individual. Trapping is a valuable endeavor. Most trappers agree that the anticipation of tending a trapline is a very enjoyable and pleasant experience.

Beavers are economically important as both a nuisance species and a source of income. Prepared pelts have monetary value and are considered marketable commodities. Many landowners recognize the beaver as part of their wealth and afford them some measure of protection. The commodity value of the annual beaver harvest is important and provides an additional reason why we need to manage this furbearer for sustained use.

Beaver fur has been utilized in various styles of garments over the years, ranging from traditional long hair to sheared and dyed garments (Bosma 2003). Fashions are unpredictable, but drive the world demand for pelts. World markets for beaver pelts frequently fluctuate and correspondingly change the price paid for pelts at local markets. Proper pelt handling and preparation as well as pelt primeness, size, and characteristics determine prices paid.

Beaver pelt values over the past 35 years are depicted in Table 3. The average Pennsylvania beaver pelt was worth \$18.47 during that period. Pelt values were relatively high during the late 1970s. Adjusting for inflation, the average beaver pelt price was \$104.34 in 1978. Since 1981, beaver pelt prices fluctuated moderately, but remained below inflation-adjusted averages of the 1970s. The total value of beaver pelts averaged \$122,899 annually, with an inflation-adjusted mean of \$242,804 annually. During 2005-2007, the average value of beaver pelts in Pennsylvania was more than \$250,000 annually.

Table 3. Beaver pelt values in Pennsylvania during 1974-2007.

Year	Annual harvest[a]	Average pelt price ($)[b]	2008 inflation-adjusted mean pelt price ($)	Total estimated value ($)	2008 inflation-adjusted total value ($)
1974	5,369	15.50	67.74	83,220	363,696
1975	3,517	17.52	70.08	61,618	246,471
1976	3,573	23.11	87.36	82,572	312,137
1977	3,227	16.46	58.43	53,116	188,553
1978	1,404	22.60	74.58	31,730	104,710
1979	3,547	35.13	104.34	124,606	370,093
1980	5,319	22.93	59.85	121,965	318,342
1981	7,015	16.49	39.08	115,677	274,146
1982	3,245	13.62	30.37	44,197	98,551
1983	5,571	17.41	37.61	96,991	209,525
1984	3,321	18.54	38.38	61,571	127,460
1985	7,232	24.74	49.48	178,920	357,839
1986	5,272	24.49	48.00	129,111	253,056
1987	6,490	19.30	36.67	125,257	237,988
1988	4,721	18.91	34.42	89,274	162,497
1989	4,678	17.09	29.74	79,947	139,123
1990	3,439	9.79	16.15	33,668	55,540
1991	4,107	13.08	20.67	53,720	84,892
1992	4,506	8.30	12.70	37,400	57,226
1993	3,603	13.00	19.37	46,839	69,790
1994	9,360	15.30	22.19	143,208	207,698
1995	6,454	19.65	27.71	126,821	178,840
1996	9,789	29.37	40.24	287,503	393,909
1997	12,628	21.73	29.12	274,406	367,727
1998	8,727	15.29	20.18	133,436	176,110
1999	8,377	16.08	20.74	134,702	173,739
2000	8,408	20.00	25.00	168,160	210,200
2001	10,934	15.86	19.35	173,413	211,573
2002	4,538	14.33	17.20	65,030	78,054
2003	7,874	15.84	18.53	124,724	145,905
2004[c]	-	16.11	18.37	-	-
2005	14,283	17.18	18.90	245,382	269,949
2006	14,210	22.14	23.69	314,609	336,635
2007	11,542	21.67	22.54	250,115	260,157
2008	9,942	18.05	18.05	179,453	179,453
35-yr avg:	6,654	18.47	36.49	122,899	242,804

[a]Annual harvest was based on mandatory tagging records during 1974-2002. Annual harvest was estimated from furtaker mail surveys in 2003, 2005-2008.
[b]Pelt prices were based on PA Trappers Association fur sale records.
[c]Annual harvest was not determined in 2004.

Pelt primeness is extremely important to trappers, fur buyers, and garment manufacturers. Primeness occurs when the guard hair and underfur has reached its maximum length, density, and finest texture, when the hair has matured with seemingly no pigmentation produced, and when the flesh surface of the pelt appears devoid of hair root pigmentation (Worthy et al. 1987). Stains (1979) noted that the roots of new hair growth move toward the skin's outer surface. The volume of blood that nourishes the fully-grown, new hair decreases resulting in a light-colored hide. The hair on unprime pelts is rooted deeper into the hide and is fed by more blood in the surrounding tissue. The inner (skin) side of unprime pelts appears gray or blue in color. If an unprime skin is shaved or sanded to reduce its thickness, the underfur roots may be cut off, causing the hair to fall out. This circumstance makes pelt primeness extremely important to fur manufacturers.

Normally, a new hair coat is developed during the spring and fall. The spring molt replaces winter pelage. Fall shedding replaces the summer coat. Some hair replacement can occur throughout the year, but in much less volume when compared to spring and fall coat changes (Stains 1979).

Time of year plays an important role in determining the price paid for beaver pelts. Bosma (2003), a senior fur grader for the North American Fur Auctions, noted that beavers caught early have blue or slate-blue leather and in most cases, have under wool on the fur side that has not grown to maximum potential. In general, beavers caught under the ice have "prime" fur developed to their maximum potential, both on the fur and leather sides. Late season or spring beavers will show dark shadowing on the leather sides around the legs or back area. This shadowing is the first indication of going "past" or "off" prime. He also warned that spring beavers tend to have a higher incidence of scars and bite marks due to territorial disputes.

In an unpublished, 1996 telephone survey of Pennsylvania fur buyers, I obtained local opinions on the timing of beaver pelt primeness from 26 randomly-selected fur dealers from all regions of the state. Survey participants identified the period of mid-December to mid-March as the time of primeness for beavers. The first week of January was recommended as the earliest start date for harvest. Peak primeness was believed to occur during the month of February by most fur buyers. Several buyers explained that the primeness period was divided into two segments. The period of mid-December through January produced *fall* beavers in Pennsylvania. Garment manufacturers normally do not shear or pluck guard hairs from these pelts (Schipper 1987). The underfur is not at maximum length. Pennsylvania fur dealers identified February to mid-March as the period when *winter* beaver pelts normally occur. The underfur of these pelts is at maximum length. The hides are often plucked, sheared, bleached, and dyed (Schipper 1987). Generally, winter beavers are more valuable than fall beavers.

Using proper trapping equipment and good set methods will reduce the chance of damage to beaver pelts. Beavers should be killed quickly to avoid damage to fur caused by the trapping device (Hall and Obbard 1987). Beaver pelts sometimes show body-gripping trap or snare damage. Body-gripping traps generally do not damage the skin. However, the trigger or dog can rub the surface guard hairs off of the pelt. If the rub is not too large, it will likely be overlooked (Bosma 2003). Improper use of snares can turn a perfectly good beaver pelt into a damaged one. Snare marks that show as a thin red line on the leather side is a bad sign (Bosma 2003). If the leather fibers are broken down, the fur is not held in by the leather. Hair slippage can occur. Snare marks that show a thin white line on the leather side generally cause no fur-dressing problems.

Proper pelt handling and preparation is often not considered when *average* pelt prices are quoted. However, the care used to properly prepare fur for sale is reflected in the price paid. When handling beavers in the field during the winter, you should not lay them on a bare ice surface (Hall and Obbard 1987). Placing harvested beavers in a burlap bag or other container will minimize guard hairs from being pulled or damaged. Beavers caught in body-gripping traps should be pulled from the water by a forelimb, rather than by the trap to prevent guard hair rubbing or loss. Care should also be taken when beavers are frozen to the trap or ice surface. A common error when boarding beaver pelts is stretching them into unnatural shapes. All beavers should be stretched into an oval, conforming to its natural shape (Hall and Obbard 1987).

The most commonly used technique for determining the size of a beaver pelt is to sum its length and width. Pelt prices are largely based on what size category a pelt falls under. Size categories under common use are listed in Table 4 (Obbard 1987).

Table 4. Standard trade name and size for beaver pelts (Obbard 1987).

Trade name		English dimensions (in)	Metric dimensions (cm)
XS -	extra small (cub or kit)	<42	<107
S -	small	42-47	107-119
M -	medium	47-51	119-130
LM -	large medium	51-55	130-140
L -	large	55-60	140-152
XL -	extra large	60-65	152-165
XXL -	blanket	65-70	165-178
XXXL -	super blanket	>70	>178

The sale of beaver castor and oil glands can provide additional income for trappers if properly cleaned and dried. Although selling beaver meat is not permitted in Pennsylvania, this food item is considered a delicacy by some. Beaver meat is lean and flavorful.

SECTION 6: POPULATION MANAGEMENT

Having the maximum amount of information available to manage a beaver population is always desirable. Population and habitat information such as number of animals, productivity, amount and distribution of suitable habitat, carrying capacity, and harvest level needed to stabilize populations are among the most useful for proper management.

Harvest management

A reasonably accurate count of the annual harvest is the minimum information on which to base beaver management decisions (Hill 1982). Without this critical harvest information, our agency has no measure of the current state of beaver management, nor where it will go in the future. Annual harvest management and monitoring is essential for safeguarding and sustaining this important furbearer resource.

In order to properly manage beaver populations, the Pennsylvania Game Commission must have the flexibility and authority to regulate the harvest in response to changing trapping pressure and local population needs. Beavers are vulnerable to overharvest because of their confinement to watercourses and easily-learned behavior and movement patterns. If harvest is too intense, beaver populations cannot offset this loss through reproduction. They have a relatively slow rate of reproduction and delayed sexual maturity. Entire local populations can be eliminated in one season of intensive trapping.

In general, harvest levels reflect the status of the beaver population. The number of beavers harvested can fluctuate widely on an annual basis for many reasons. In the past, the following beaver harvest management parameters influenced trapper take in Pennsylvania:

1. Season dates and length
2. Bag limits
3. Trap type restrictions
4. Trap placement restrictions
5. Pelt price
6. Weather conditions

In Missouri, Erickson (1981) examined statewide the beaver harvests in relation to pelt value, season length, pelt value of other furbearers, temperature-indexed season length, snow-indexed season length, and beaver damage complaints. Among these variables, only season length significantly accounted for annual variation in the beaver harvest.

Wildlife agencies in northeastern North America have established seasons ranging from 45-187 days during mid-October through the end of April (Fig. 10). Beaver season length and timing of the season vary considerably among northeastern jurisdictions. Trapping pressure and winter weather conditions are key considerations when establishing beaver seasons. Season length appears to greatly influence the beaver harvest in Pennsylvania.

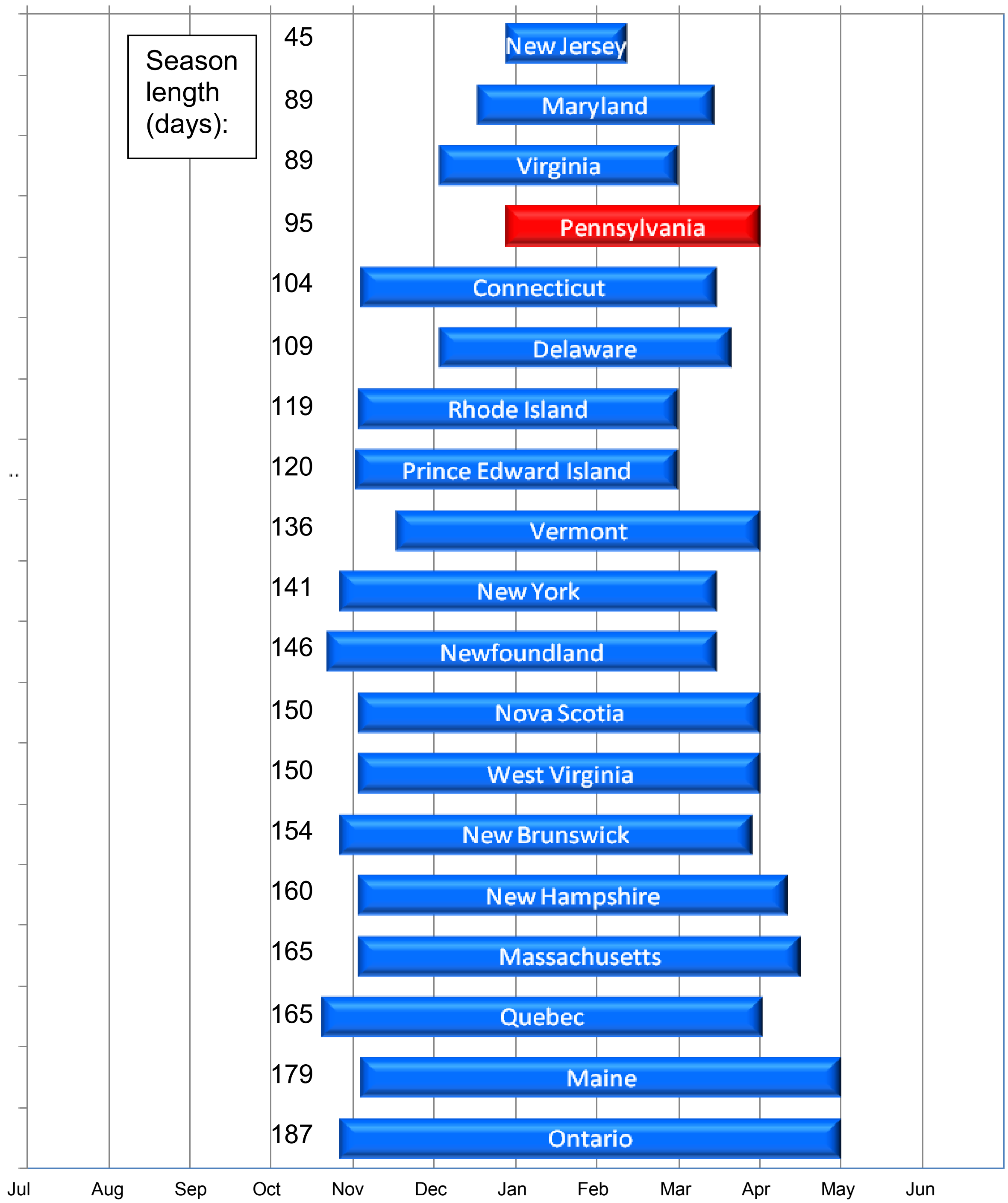


Figure 10. Beaver seasons among northeastern jurisdictions in North America.

Adults are more susceptible than kits or yearlings to winter trapping (Payne 1975). Both adult males and females are equally vulnerable to harvest. The vulnerability of kits to trapping is related to trapping distance from the lodge (Payne 1975). Wilsson (1971) observed kit activity concentrated in and around the lodge for more than one year. Kits did not repair dams or help construct a winter food cache. Payne (1975) believed that kits were very susceptible to harvest within 9 m (30 ft) of the lodge. When first established, Pennsylvania's regulation prohibiting placement of traps within 15 feet of a lodge was an important step in protecting kits and yearlings. In areas where beaver populations are declining, this regulation will help recovery efforts.

Pennsylvania trap type restrictions basically limit the number of body-gripping traps and total trapping devices that may be used in a WMU. When used properly, body-gripping traps are very efficient at taking beavers. The purpose of this regulation was to provide trapping opportunity to the most participants by slowing or limiting beaver take. Beaver snares are very effective and selective in open water and under the ice, if set properly. Snares and foothold traps are especially effective on trap-shy beavers. Few, if any, cage traps are used by trappers to harvest beavers. Limits on total trapping devices were also established to increase opportunity among trappers.

One purpose of bag limits is to help control harvest success rates. As was true for trap type regulations, bag limits also help to provide more trappers the opportunity to harvest a beaver. Whether a trapper pursues beavers on a full-time basis or is a weekend trapper, established maximum bag limits within WMUs help equalize differences in skill levels, available time, and access to private lands.

We compiled information on the level of individual trapper success based on past pelt-tagging data. The number of trappers taking greater than 30 beavers per season comprised less than 3% of the total harvest for each year (Table 5). Except during the 2002-03 season, when trapping conditions were extremely difficult, the proportion of trappers categorized within each harvest success range did not change annually. This consistency in the proportion of trappers falling into harvest success groups each year suggests that trapping effort may be uniform among trappers. Most trappers may have traditional trapping areas and put forth the same amount of trapping effort each year.

Table 5. Number of beaver trappers by harvest success group during 1997-2002.

Season	Beaver harvest per trapper								Total successful beaver trappers
	1-5	6-10	11-15	16-20	21-30	31-45	46-60	> 60	
1997	1,060 (54)[a]	573 (29)	161 (8)	112 (6)	35 (2)	8 (1)	2	0	1,951
1998	611 (52)	340 (29)	107 (9)	78 (6)	36 (3)	11 (1)	2	1	1,186
1999	612 (53)	325 (28)	102 (9)	77 (7)	30 (2)	12 (1)	3	1	1,162
2000	519 (48)	310 (29)	116 (11)	98 (9)	19 (2)	14 (1)	5	0	1,081
2001	715 (50)	422 (29)	124 (9)	105 (7)	45 (3)	22 (2)	4	1	1,438
2002	531 (65)	192 (24)	52 (6)	27 (3)	17 (2)	2	0	0	821

[a] Percentage of successful beaver trappers are in parentheses.

Each year, we define bag limits for each WMU as well as a statewide maximum bag limit and publish these in the Hunting and Trapping Digest. Appendix 2 depicts present WMU boundaries. Regulations pertaining to WMUs were sometimes grouped into physiographic units (WMU groups). A WMU group includes all units beginning with the same number. For example, Group 1 would include WMUs 1A and 1B. Currently, WMU groups 1 (1A-B) and 3 (3A-D) have bag limits of 20 daily and 40 per season. Groups 4 (4A-E) and 5 (5A-D) have limits of 10 daily and 10 per season. WMU group 2 is split into areas with different bag limits. WMUs 2A-D have limits of 10 beavers daily and per season. Bag limits in WMUs 2E-G are 20 daily and 20 per season. Related beaver regulations are summarized in Appendix 1.

Seasonal harvest by trappers was not influenced by the statewide maximum bag limit during 1997-2002 (Table 6). Few trappers who achieve the maximum bag limit in one area travel to other areas in pursuit of another maximum bag limit. Based on beaver harvest success per trapper and the proportion of trappers harvesting <20 beavers (Table 5), most (88-95%) Pennsylvania trappers do not reach the maximum bag limit within the management area they trap. Factors such as a trapper's available time and private land access may limit harvest success. Current bag limits and those of the recent past do not appear to significantly impact the total beaver take for most trappers.

Table 6. Beaver season bag limits, trapper success, and harvest during 1997-2002.

Season	Maximum season bag limit listed in digest	Greatest harvest by an individual trapper	Total successful beaver trappers	Statewide harvest total
1997	76	60	1,951	12,628
1998	76	61	1,186	8,727
1999	76	69	1,162	8,377
2000	76	60	1,126	8,408
2001	116	97	1,438	10,934
2002	116	40	821	4,538

Pelt price and weather conditions are unpredictable. During seasons of favorable trapping weather (1997-98 and 2001-02) in Pennsylvania, a greater number of beaver trappers were successful, resulting in a larger harvest (Table 6). Pelt price is controlled by fashion trends and foreign export demands. Although this parameter is the major motivational force behind trapping participation, we cannot anticipate pelt price levels, nor the resulting level of trapper effort.

Current harvest estimates in Pennsylvania are based on furtaker mail-survey results. During 1990-2002, beaver harvest was determined from both mandatory tagging data and estimated from furtaker mail survey (Fig. 11). In 13 years, 6 harvests were outside of 95% confidence interval boundaries. All were significantly lower than the estimated harvest from the furtaker survey. During years of high harvest, the accuracy of the information gained may be questionable.

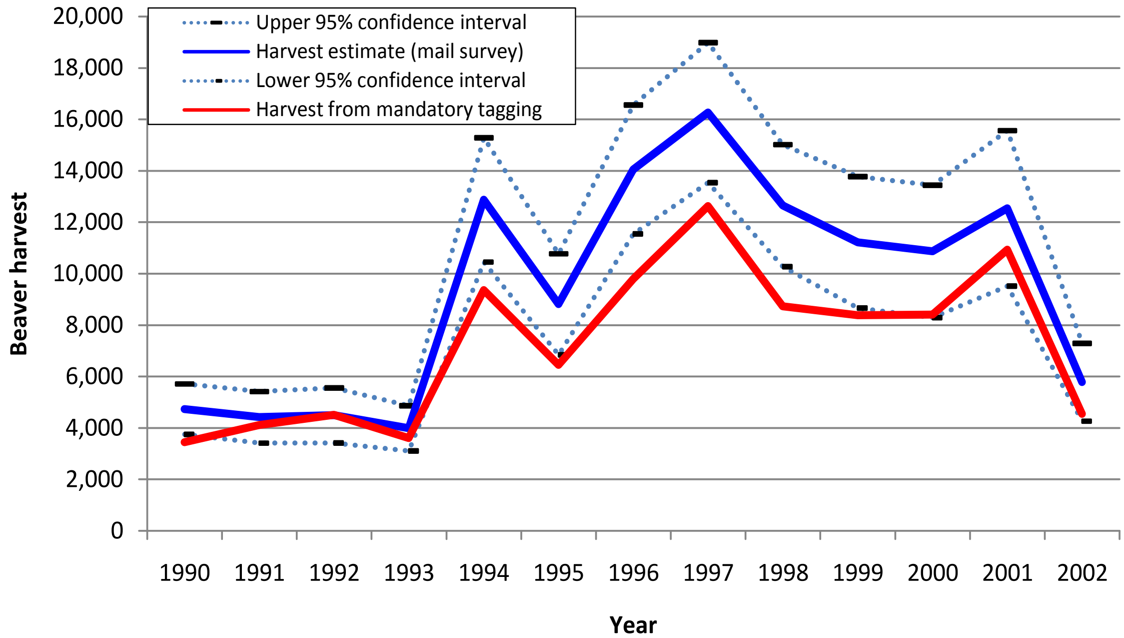


Figure 11. Beaver harvest estimates with 95% confidence intervals from furtaker mail survey and harvest determined by mandatory tagging during 1990-2002.

Current harvest trends

With the advent of new WMUs in 2003, harvest data conversion was necessary to separate county-based information into appropriate WMUs. Where one or more WMU boundaries intersected portions of a county, beaver harvest totals were divided among WMUs in proportion to the land area they covered within that county. The required assumption was that the beaver harvest was equally distributed throughout the counties containing more than one WMU. I acknowledge that this assumption may have been violated in some cases. However, this was the only way past county-based data could be converted to WMU-based harvest totals. Beaver harvest and trend information within each Wildlife Management Unit and physiographic unit (WMU group) during 1979-2007 is depicted in Appendix 4. These 30-year trends showed either increasing or stable harvests for all WMUs and physiographic areas.

Beaver harvest trends within each WMU and WMU group over the past 4 years are reported in Table 7. Significant ($P \leq 0.05$) negative trends were detected in WMU 1A and in the statewide harvest during 2005-2008 seasons. Weak ($P<0.15$) negative trends occurred in WMUs 2B, 4D, and 5D. These negative beaver harvest trends may be early warning signs of decreasing populations. The beaver harvest in these management units should be closely monitored. Among grouped WMUs, groups 1, 3, 4, and 5 showed negative correlation. However, no decreasing WMU group trend was significant. Although no WMU showed a significant positive harvest trend, WMUs 2A and 2F had increasing trends that were weakly ($P=0.18$, $P=0.20$, respectively) correlated.

Table 7. Beaver harvest trends by Wildlife Management Unit (WMU) and WMU group based on furtaker mail survey results during 2005-2008. Pearson correlation coefficients (r) and significance levels (P) were calculated for each 4-year harvest trend.

WMU	Season 2005	2006	2007	2008	r	P
1A	2,395	2,285	1,295	762	-0.96	0.04
1B	2,257	2,664	1,976	1,490	-0.78	0.22
Group 1[a]	4,652	4,949	3,271	2,252	-0.91	0.09
2A	386	292	461	762	0.82	0.18
2B	366	292	106	137	-0.91	0.09
2C	396	715	480	603	0.36	0.64
2D	732	379	806	535	-0.11	0.89
2E	257	542	288	410	0.20	0.80
2F	356	628	969	774	0.80	0.20
2G	960	574	173	455	-0.76	0.24
Group 2	3,453	3,422	3,283	3,676	0.42	0.58
3A	851	531	787	307	-0.71	0.29
3B	505	942	681	501	-0.17	0.83
3C	1,178	1,841	1,113	569	-0.63	0.37
3D	396	801	528	387	-0.20	0.80
Group 3	2,930	4,115	3,109	1,764	-0.60	0.40
4A	386	130	106	148	-0.73	0.27
4B	238	119	221	46	-0.68	0.32
4C	495	87	67	216	-0.56	0.44
4D	505	238	221	182	-0.86	0.14
4E	247	141	365	387	0.73	0.27
Group 4	1,871	715	980	979	-0.62	0.38
5A	257	184	288	216	-0.05	0.95
5B	188	303	288	239	0.34	0.66
5C	119	184	48	57	-0.66	0.34
5D	69	76	29	23	-0.88	0.12
Group 5	633	747	653	535	-0.58	0.42
Unknown WMU	742	260	249	739		
Total	14,283	14,210	11,542	9,942	-0.95	0.05

[a]WMU group includes all units beginning with the same number. For example, Group 1 would include WMUs 1A and 1B.

Population modeling

Population growth is controlled by the number of animals added to the population and the number removed from the population. Given the hypothetical scenario of unlimited, suitable habitat and no mortality, beaver populations can quickly increase. If we begin with two adult beavers and assume sexual maturity at age 2 and average litter size of 4, we can create a simple population growth model (Table 8). After 10 years with no mortality, the population grew from 2 to 608 beavers. Excluding the first year, the average population increase over this period is approximately 60% per year.

Table 8. Hypothetical growth of a beaver population experiencing no mortality, beginning with two adults, and assuming first reproduction at age 2 and litter size of four.

	Year										
Age Class	0	1	2	3	4	5	6	7	8	9	10
Adults (>2 yrs old)	2	2	2	2	6	10	14	26	46	74	126
2 year olds	0	0	0	4	4	4	12	20	28	52	92
1 year olds	0	0	4	4	4	12	20	28	52	92	148
Kits	0	4	4	4	12	20	28	52	92	148	252
Total	2	6	10	14	26	46	74	126	218	356	608
Annual increase (%)	-	300	66	40	86	77	61	70	73	63	71

Compared to many other rodents, beavers have relatively low natality, low mortality of young, high parental care, prolonged behavioral development, and high adult longevity in the absence of harvest (Hodgdon and Lancia 1983). Limiting factors that slow or stop beaver population growth include excessive harvest, limited food and water resources, weather and temperature extremes, intrauterine loss, and mortality from disease, natural predation, and accidents. Controlling the beaver population levels through annual harvest will minimize loss from most other sources.

Beaver population densities are usually expressed as the number of individuals per linear unit in well-defined watercourses or per area unit where wetlands are spread widely. The number of individuals in a population is estimated from colony counts. However, Baker and Hill (2003) warned that unless estimates of the average colony size are based on local data and not from general literature, calculated population sizes are meaningless. The practice of multiplying the number of colonies by a general, average number of individuals per colony to derive a population estimate adds false precision to the estimate.

Estimates of beaver colony size are difficult to obtain, but are important when setting harvest quotas (Novak 1987). In Pennsylvania, Brenner (1962) counted beavers in three active lodges using a night spotting scope. He later partially dismantled the same lodges and counted the beavers as they exited. Both methods produced the same colony count. In the Rocky Mountains, Hay (1958) drained beaver ponds and used smoke to drive beavers from their lodges in order to count them. Trappers were used by Payne (1982) to completely trap out beaver colonies to determine average colony size. Novak (1977) developed a formula using age and reproductive data from trapped beavers to calculate a mean family size. Swenson et al. (1983) modified the equation by adding estimates of fecundity for each age class of beavers. Estimating mean colony size from age and reproductive data of harvested beavers may be the most feasible method available.

Basic assumptions included in Pennsylvania's past beaver population model, such as the average number of beavers per active colony, may have been inaccurate for many areas of the state. We used Brenner's (1964) estimate of 6.2 beavers per active colony and applied that figure to the beaver colonies throughout the Pennsylvania.

The removal rate used in our past model to stabilize a beaver colony may have also been inaccurate. An average harvest of 1.5 beavers per active colony of 6 beavers may not have been achieved statewide to annually stabilize colony size, since population estimates increased throughout the 14-year monitoring period (Fig. 6). This 25% harvest rate is less than that recommended by most researchers. Harvest rates necessary to stabilize beaver populations depend on habitat conditions. In excellent Ontario habitat, Novak (1977) recommended a 43% harvest rate. Other investigators reported 20-25% in Newfoundland (Payne 1984), 32% in Ohio (Henry and Bookhout 1969), and 25-70% in the U.S. rocky mountain region (Yeager and Rutherford 1957). However, Novak (1987) suggested using a 30% harvest rate to stabilize beaver populations regardless of habitat type in Ontario. An annual harvest rate of 2 beavers per active colony of 6 (33%) might have more effectively stabilized colony size in Pennsylvania.

Trapping effort is largely dependent upon the strength of the fur market. However, the annual beaver harvest and inflation-adjusted pelt price in Pennsylvania were not correlated (R^2=0.20, $P>0.05$; Fig. 5). Many other factors likely influence harvest success such as weather, season length, and trapper experience. Sufficient, but not excessive, annual harvest is essential for successful beaver management. Pelt prices must be high enough to maintain interest among beaver trappers. As long as beaver pelt prices remain relatively constant and at reasonable levels, we can effectively use trapping as a beaver management tool.

SECTION 7: RECOMMENDATIONS AND RESEARCH NEEDS

Based on our current knowledge of beaver life history and management, we can identify relatively specific needs or strategies required to fulfill our objectives, goals, and ultimately our beaver management mission. Our beaver management mission is to establish stable beaver populations in balance with their habitat for the benefit of wetland wildlife species and human users through proper population monitoring, harvest management, and damage control. The goals of Pennsylvania's beaver management are to (1) establish sustained beaver populations within suitable habitat, (2) monitor the beaver harvest, (3) minimize beaver damage complaints, (4) increase public awareness and knowledge of the benefits of beavers and their habitat, and (5) provide opportunities to use and experience beavers. Objectives identify the necessary steps to achieve each of the five goals. Strategies consisting of actions and research needs help us to attain each objective. The following recommendations and research needs lay the foundation for completing the steps necessary to achieve our beaver management mission.

Population status and trend monitoring

Annual beaver population monitoring [Objective 1.1] is necessary to maintain numbers at levels in balance with their habitat and at levels accepted by the public. General beaver population status information should continue to be obtained from annual WCO furbearer surveys [Strategy 1.1.1]. In addition, beaver densities should be monitored within each WMU to determine population stability. Most beaver monitoring methods previously used in Pennsylvania focus on population trends, indices, and estimates of number and density.

Langlois (1999) compared beaver survey methods to estimate colony densities in Massachusetts. She found that although aerial surveys were thought to provide a relatively inexpensive assessment method over a large area in a short amount of time (Swank and Glover 1948), direct aerial counts did not provide valid estimates of total active beaver colonies in Massachusetts. Aerial survey accuracy varied by survey area and ranged from 17-64%. Ground survey accuracy was greatly influenced by the experience of the observer. Novice observers accurately found 71% of beaver habitat sites and 63% of active colonies. Experienced observers found 94% of the habitat sites and 83% of active colonies. Ground surveys provided the most accurate survey results. Unless the observer bias of novice surveyors can be corrected, she recommended that only experienced observers be used to conduct ground surveys.

Currently, at least 5 of 19 northeastern states and eastern Canadian provinces conduct some sort of plot or transect survey to monitor beaver populations (Appendix 5). The Canadian provinces of Prince Edward Island and Nova Scotia use aerial survey methods. New York, Rhode Island, and Vermont conduct ground surveys for beavers annually.

A trapper's census was judged an imprecise measure of population size over a large area (Gunson 1970). Knowledge of beaver habits and sign are important, but concerns over data accuracy and thoroughness of survey efforts preclude using trappers or other non-wildlife professionals for field surveys.

In Pennsylvania, an annual colony count using ground surveys is needed within each WMU or physiographic unit (WMU group) to monitor population levels [Strategy 1.1.2]. A complete colony count might be achieved in some low-density beaver areas. We need to survey sample plots where beavers are more densely populated. In the 2008 WCO furbearer questionnaire (Appendix 3), we asked field officers if they felt they could locate and accurately count all known beaver colonies within their districts. Forty-three percent of WCOs responding to the survey said that they could achieve a total beaver colony count within their district. Most areas where complete colony counts were possible occurred in the southern half of Pennsylvania (Fig. 12). Beaver colonies were too numerous or too difficult to count in 59% of the WCO districts. No colony count information could be obtained for 4% of the districts.

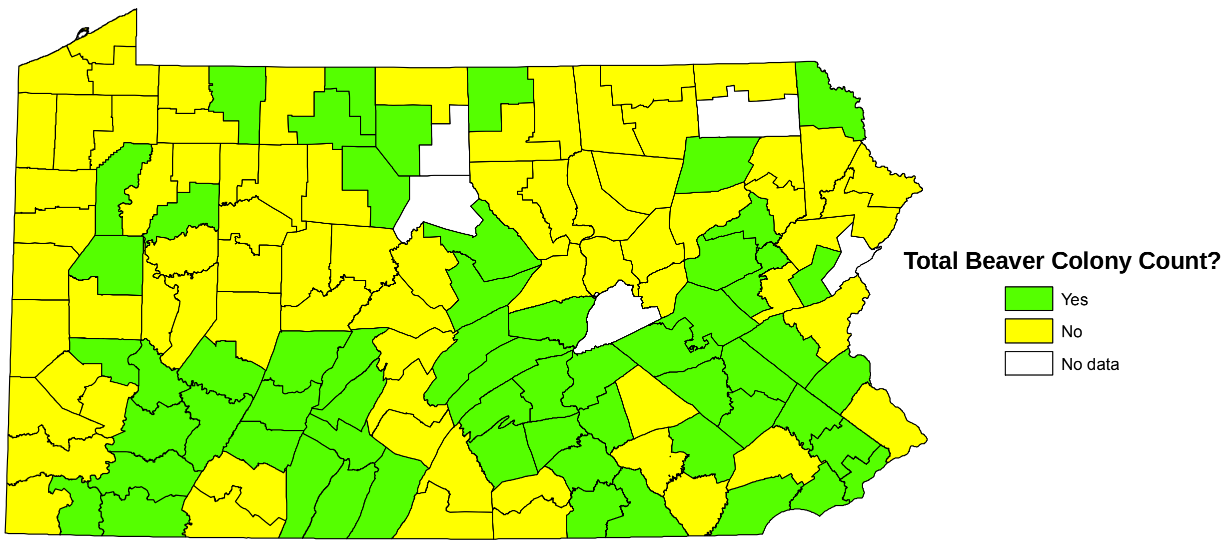


Figure 12. Distribution of Wildlife Conservation Officer districts where field officers believed they could or could not locate and accurately count all known beaver colonies in 2008.

To assure population monitoring accuracy [Objective 1.2], we need to require mandatory training of all survey participants to establish consistency in beaver sign identification and in following survey protocol [Strategy 1.2.1]. As part of the survey procedures, GPS coordinates of each colony would be recorded. The spacing of located colonies could be important in identifying duplicate counts of the same colony and monitoring the distribution of colonies within the survey area. Criteria for determining colony type (single, pair, or family) should also be developed and incorporated into the survey [Strategy 1.2.2]. Habitat suitability data collection could be part of this field survey as well.

Population parameter monitoring

The change in the abundance of a population in response to a management action can be detected in basic measures of population parameters. Population change is often viewed as a result of mortality, reproduction, immigration, and emigration. The development of a population model requires estimates of these demographic parameters. We need to monitor beaver population changes within each WMU or physiographic unit (WMU group) by developing a population model using the best demographic measures available [Objective 1.3].

We need to determine the basic reproductive parameters (litter size, age at first reproduction, reproductive rate) of beaver populations within each WMU or physiographic unit [Strategy 1.3.1]. The only fecundity information on beavers was collected nearly 50 years ago (Brenner 1960) and was limited to Crawford County, Pennsylvania. We know little about litter size, intrauterine mortality rates, and age at first reproduction and whether these parameters differ among WMUs.

Measures of reproductive performance and litter size including counts of corpora lutea, corpora albicantia, placental scars, and fetuses are useful in estimating fecundity. Wigley et al. (1984) found that counts of corpora lutea, placental scars, and fetuses yielded statistically similar estimates of litter size, despite pre- and post-implantation losses. Natality and recruitment are key reproductive parameters in monitoring populations. However, many northeastern states and eastern Canadian provinces do not routinely collect this type of information as part of annual monitoring (Appendix 5). Those jurisdictions that examine beaver carcasses from harvested, incidentally taken, or road-killed beavers monitor age, sex, reproductive status, and body condition. The sex ratio of trapped beavers often does not differ from 1:1. Sex ratio information does not appear to serve a useful purpose in beaver management (Novak 1987).

As practiced in Pennsylvania's deer management program, reproductive potential can be used as a measure of beaver population health. Habitat for beavers differs regionally. However, we have no measure of what habitat differences might exist nor how these differences affect health and reproductive success. Knowledge of this basic reproductive information is also necessary for population model building.

Although starvation, weather and temperature extremes, intrauterine loss, and disease, predation and accidents account for many beaver deaths, regulated harvest is the most significant source of beaver mortality in Pennsylvania. Harvest mortality information specific to each age group or age class should be collected [Strategy 1.3.2]. Non-harvest mortality information is also valuable and should be obtained when possible.

We should begin collecting information on beaver reproductive potential as well as age structure within each WMU or physiographic unit. Harvested beaver carcass collections will be necessary. The primary purpose of collecting reproductive status and age data will be to gather information needed to calculate average colony size using the methods developed by Novak (1977) and Swenson et al. (1983). These data in combination with annual colony counts will provide estimates of population size within each WMU or WMU group.

We should determine how beaver bag limits, season length, trap distance from beaver structures, and number and type of trapping devices influence the rate of harvest [Strategy 1.3.3]. With the new Point of Sale licensing system in place, we should identify and survey beaver trappers to determine harvest characteristics such as number of nights trapped, types of traps and sets used, number of beavers harvested per colony, dates trapped/captured, and WMUs trapped. Knowing the characteristics of beaver trappers will help determine how trapping seasons, bag limits, and regulations affect annual harvest rate.

When more liberal beaver trapping seasons, bag limits, and regulations are initiated, the beaver harvest is influenced in varying degrees. We can speculate how each regulatory action impacts the beaver harvest (Table 9). However, knowing beaver trapper characteristics would help us understand how regulatory actions influence harvest rate.

Table 9. Probable influence of liberalizing seasons, bag limits, and regulations on the beaver harvest.

Regulatory action	Influence on beaver harvest
No **trap placement** restriction (trapping allowed any distance from beaver lodges, bank dens, feed beds, dams, or other structures)	Very high harvest increase. Adults as well as juvenile and subadult beavers will be highly vulnerable to harvest. Many colonies can be completely trapped out.
Increase number of **body-gripping traps** allowed	High harvest increase. Body-gripping traps are highly efficient. River otters are more vulnerable to accidental capture in body-gripping traps.
Increase **season length**	Moderate harvest increase. Harvest levels during short seasons are highly dependent upon weather conditions. Longer seasons are influenced less by weather.
Increase **bag limit**	Low to moderate harvest increase. This regulation may allow for more equal opportunity for trappers to harvest beavers. Most beaver trappers (80%) catch less than 10 beavers per year.
Increase number of total **trapping devices** allowed	Low to moderate harvest increase. This regulation will benefit trappers running long traplines.

Habitat assessment

In order to identify suitable beaver habitat and assess habitat needs within each WMU, we should create a GIS-based habitat suitability model for Pennsylvania [Objective 1.4]. We need to identify beaver habitat and quantify suitable habitat as well as potential beaver habitat [Strategies 1.4.1, 1.4.2]. Maringer and Slotta-Bachmayr (2006) developed a beaver habitat model using GIS technology for European beavers in Austria with the major parameters of topography, hydrology, and vegetation. This model has not been tested, but the framework for analysis has been developed.

Beaver relocation

Trapping and transferring beavers has been used to create new populations or augment small populations to increase population size. Although beaver relocations have occurred for decades in Pennsylvania, the success of this practice has never been evaluated [Objective 1.5].

Transplanted beavers may or may not stay at release sites. Some move great distances following release. Hibbard (1958) recorded a 238 km (148 mi) dispersal movement in North Dakota after trap and transfer. However, average dispersal distances were 6.4-14.6 km (4-9 mi) among beavers released in streams (Hibbard 1958, Knudsen and Hale 1965, Berghofer 1961). In potholes and ponds Knudsen and Hale (1965) observed average movements of only 3.2 km (2 mi). This finding led researchers to recommend that nuisance beavers be moved to ponds and lakes without outlets.

Dispersal distances and survival of relocated beavers depends upon habitat suitability, timing of release, sex, age, number released, family composition, predation, and disease (Baker and Hill 2003). We should evaluate the practice of trap and transfer for establishing colonies in new locations in Pennsylvania. Movement patterns and survival should be assessed for transferred beavers [Strategy 1.5.1]. The release site habitat characteristics, season of year at time of release, and the age and sex of trap-and-transferred beavers should be assessed for successful and unsuccessful population establishment [Strategy 1.5.3]. The cost of trapping and transferring beaver should also be assessed [Strategy 1.5.2].

Beaver populations on public lands

The ecological and environmental benefits of beavers and the habitat they create are desirable on all public lands. Where possible, we should manage beaver populations on public lands for maximum wildlife benefit [Objective 1.6].

As part of our state game land planning process, we should attempt to integrate beaver habitat needs into our plans to benefit beaver colony establishment and long term food supply [Strategy 1.6.1]. In particular, aspen stand management in riparian areas would greatly improve beaver food supply and increase the chances for beaver pond establishment in the area. Integrating beaver forage management into the state game lands planning process will not only benefit area beaver populations, but also a host of other wildlife species.

In some areas of Pennsylvania, beaver populations have been suppressed for many years. Excessive trapping, poor habitat, and human intolerance of beaver activity are some reasons for these low population areas. Many state-owned lands open to public trapping support no or very few beaver colonies. Excessive harvest is the primary reason for this scarcity in these public areas.

We should attempt to transplant beavers from nuisance areas to suitable habitat on public lands for the purpose of establishing new colonies [Strategy 1.6.2]. We should also establish *protected* beaver colonies on selected state game lands to create population refuges from which range expansion can occur [Strategy 1.6.3]. Our focus should be on those areas with depressed or nonexistent beaver populations. Our plan is to protect these colonies from legal harvest and allow them to establish wetland habitat, while acting as centers of population expansion to other parts of the watershed.

Beaver harvest monitoring

Before beaver trapping regulatory changes can be proposed, we need to evaluate the accuracy of estimating the beaver harvest from furtaker survey results [Objective 2.1]. If a correction factor will bring harvest estimates and their corresponding 95% confidence intervals within harvest figures determined from mandatory harvest reporting, we can use furtaker survey harvest estimates [Strategy 2.1.1]. Otherwise, we should consider other options including some sort of mandatory beaver harvest reporting [Objective 2.2, Strategy 2.2.1]. Mandatory sealing may not be necessary, but compulsory reporting would greatly improve the accuracy of our harvest data. New York currently requires successful beaver trappers to complete a possession tag (contains name, address, date and location of harvest) for each harvested beaver and either present it when the pelt is sealed or mail it to the agency headquarters. Those trappers who mail in their possession tags will receive beaver tags in the mail and are permitted to seal their pelts themselves.

We should establish additional measures of harvest or population trend [Objective 2.3] such as some form of catch per unit effort [Strategy 2.3.1]. The Point of Sale licensing system may allow us to survey a large proportion of beaver trappers to gain trapping effort information including number of days trapped and number of traps used each day. Asking trappers to complete a beaver trapping log may also help obtain this type of data. Harvest density estimates such as catch per mile of stream or square mile of area may also be used as an additional trend indicator. However, accurate harvest data is necessary to use this harvest density estimator. Comparisons of this measure among other northeastern jurisdictions in North America may be useful (Table 10).

Table 10. Beaver harvest and harvest density in northeastern jurisdictions in North America during 2007-08.

Jurisdiction	Currrent harvest	Current harvest density: Land area per harvested beaver (km^2/beaver)	Current harvest density: Land area per harvested beaver (mi^2/beaver)	Current harvest density: Linear stream length per harvested beaver (km/beaver)	Current harvest density: Linear stream length per harvested beaver (mi/beaver)
Maine	6,357	12.6	4.9	11.4	7.1
Massachusetts	848	23.9	9.2	15.6	9.7
New Brunswick	7,643	9.3	3.6	8.9	5.5
New Hampshire	2,210	10.5	4.1	7.9	4.9
New Jersey	653	30.9	11.9	10.1	6.3
New York	15,111	8.1	3.1	5.6	3.5
Nova Scotia	3,491	15.3	5.9		
Pennsylvania	11,542	10.1	3.9	11.6	7.2
Prince Edward Island	278	20.4	7.9		
Rhode Island	63	43.0	16.6	35.6	22.1
Vermont	1,244	19.3	7.5	9.2	5.7
Virginia	3,367	30.5	11.8	24.1	15.0
West Virginia	1,487	41.9	16.2	34.9	21.7

We could also require trappers to obtain a free permit through the Point of Sale license system in order to trap beavers. This arrangement would enable us to survey and better communicate with beaver trappers and allow us to obtain more accurate harvest information.

Beaver regulations

The current beaver regulations are complicated, to say the least (Table 11). We should develop more understandable beaver trapping regulations to improve trapper adherence to and knowledge of trapping rules [Objective 2.4]. We need to simplify *combined* WMU bag limits and evaluate the influence of regulations such as trap distance restriction near beaver structures and number and type of traps permitted [Strategy 2.4.1]. Changes may not be warranted, but we should have strong justification for keeping these regulations in place. Bag limit regulations are particularly confusing. Within WMUs with the same daily/season limits, the bag limit applies to the combined areas. For example, under current regulations, the bag limit is 20 daily and 40 per season in the combined area comprising WMUs 1A-B and 3A-D; 10 daily and 10 per season in the combined area of WMUs 2A-D, 4A-E, and 5A-D; 20 daily and 20 per season in the combined area of 2E-G. There are essentially 3 independent beaver trapping areas with respect to bag limits with a subset of special regulations which apply to specific WMUs.

Table 11. Current (2010) beaver season, bag limits, and special regulations among wildlife management units in Pennsylvania.

<table>
<tr><th>Wildlife Management Unit</th><th>Combined[a] bag limit (daily/season)</th><th>Body-gripping trap limit</th><th>Trap placement near lodges or dams</th><th>Trap/Snare limit</th><th>Season dates</th></tr>
<tr><td>1A</td><td>20/40</td><td>2</td><td rowspan="5">15-foot restriction</td><td rowspan="8">20 total devices allowed
Up to 10 traps
Up to 20 snares
(statewide)</td><td rowspan="8">26 Dec-
31 Mar
(statewide)</td></tr>
<tr><td>1B</td><td>20/40</td><td>10</td></tr>
<tr><td>2A-D</td><td>10/10</td><td>2</td></tr>
<tr><td>2E-G</td><td>20/20</td><td>2</td></tr>
<tr><td>3A</td><td>20/40</td><td>10</td></tr>
<tr><td>3B-D</td><td>20/40</td><td>10</td><td>No restriction</td></tr>
<tr><td>4A-E</td><td>10/10</td><td>2</td><td rowspan="2">15-foot restriction</td></tr>
<tr><td>5A-D</td><td>10/10</td><td>2</td></tr>
</table>

[a]Bag limits are combined within Wildlife Management Units (WMUs) with the same daily/season limits. In other words, the bag limit is 20 daily and 40 per season in the combined area comprising WMUs 1A-B and 3A-D; 10 daily and 10 per season in the combined area of WMUs 2A-D, 4A-E, and 5A-D; 20 daily and 20 per season in the combined area of 2E-G.

Definitions of beaver structures such as lodge, dam, and food cache should be developed [Strategy 2.4.2]. Many *gray* areas exist in interpreting regulations involving these beaver structures. Uniform interpretation of beaver regulations by trappers and WCOs is important to protect beavers from harvest where and when necessary.

If biological and social carrying capacities of beaver populations are known within each WMU, we could develop a beaver management decision matrix outlining seasons, bag limits, and other regulations recommendations based on beaver biological and social capacities. An example of this decision matrix is depicted in Table 12. Parameters and regulatory actions comprising this decision matrix would change as updated information becomes available. Currently, beaver density information is lacking. Before we can use this decision matrix, we need population density information. We can estimate WMU-level damage complaint information using present WCO furbearer surveys. However, we can accurately compile this information by tracking complaints by WMU in future WCO furbearer surveys.

Table 12. Possible beaver management decision matrix depicting regulatory action or response based on population density within suitable habitat and damage complaint levels within a WMU.

Biological capacity: Population density within suitable habitat (3-year mean)	Conditions within a Wildlife Management Unit	Social capacity: Damage complaint level (3-year mean) — Extremely few or no damage complaints < 0.25 complaints/ 100 mi^2	Low to medium 0.25-5 complaints/ 100 mi^2	High 6-10 complaints/ 100 mi^2	Extremely high, socially unacceptable level > 10 complaints/ 100 mi^2
	Extremely low density or no beavers <10 beavers/100 mi^2	[1]Trap placement and bank den restriction B-gripping limit =2 Season =15 days Bag limit = 2 Device limit =2/4	Trap placement and bank den restriction B-gripping limit =2 Season =15 days Bag limit = 2 Device limit =2/4	Trap placement and bank den restriction B-gripping limit =2 Season =95 days Bag limit = 2 Device limit =2/4	Trap placement and bank den restriction B-gripping limit =2 Season =95 days Bag limit = 2 Device limit =2/4
	Low to medium density 11-200 beavers/ 100 mi^2	Trap placement and bank den restriction B-gripping limit =2 Season =95 days Bag limit = 5 Device limit =10/20	Trap placement and bank den restriction B-gripping limit =2 Season =95 days Bag limit = 5 Device limit =10/20	Trap placement restriction B-gripping limit =2 Season =95 days Bag limit = 5 Device limit =10/20	Trap placement restriction B-gripping limit =10 Season =95 days Bag limit = 5 Device limit =10/20
	High density 201-400 beavers/ 100 mi^2	Trap placement restriction B-gripping limit = 10 Season = 95 days Bag limit = 20 Device limit =10/20	Trap placement restriction B-gripping limit = 10 Season = 95 days Bag limit = 20 Device limit =10/20	Trap placement restriction B-gripping limit = 10 Season = 95 days Bag limit = 20 Device limit =10/20	No trap placement restriction B-gripping limit = 10 Season = 95 days Bag limit = 20 Device limit =10/20
	Extremely high density >400 beavers/100 mi^2	No trap placement restriction B-gripping limit = 10 Season = 95 days Bag limit = 20 Device limit =10/20	No trap placement restriction B-gripping limit = 10 Season = 95 days Bag limit = 20 Device limit =10/20	No trap placement restriction B-gripping limit = 10 Season = 95 days Bag limit = 20 Device limit =10/20	No trap placement restriction B-gripping limit = unlimited Season = 95 days or more Bag limit = unlimited Device limit = unlimited

[1]Trap placement restriction (lodge/dam) = trapping not allowed within 15 feet of any beaver lodges, feed beds, dams, or other structures.
Bank den restriction = trapping not allowed within 15 feet of any beaver bank den above or below the water surface.
B-gripping limit = maximum number of body-gripping traps allowed.
Season = season length in days.
Bag limit = seasonal take limit.
Device limit = total traps allowed / total combined snares and traps allowed.

Damage management

We should attempt to minimize beaver damage complaints through proper beaver population management and landowner educational efforts. Complaints should be addressed promptly. Relocation or elimination of problem beavers may be necessary, but cultural methods should be first considered. If landowners can wait until the legal beaver season starts, trappers would welcome the opportunity to remove problem beaver. Landowner-WCO cooperation and communication is critical to developing the best solution for the beaver damage circumstances.

The WCO furbearer questionnaire should be conducted annually to continue to monitor the frequency of beaver damage complaints [Objective 3.1, Strategy 3.1.1]. We should add questions to the survey regarding types of beaver complaints received in order to monitor any change in damage types. The last WCO survey of this type was conducted in 1995. We currently do not monitor how many problem beavers are relocated or eliminated annually. A question concerning the fate of problem beavers should be added to the annual WCO furbearer questionnaire.

We should assess the need for public outreach with respect to dealing with beaver damage [Objective 3.2]. By conducting a survey to determine the public's knowledge of beavers, benefits of beaver habitat, and options for damage control [Strategy 3.2.1] as well as the public's desired beaver population level, we could better identify information and educational needs. Outreach directed at the public's beaver knowledge shortcomings will likely reduce landowner beaver complaints.

Outreach and consumptive use

In order to increase the public awareness of the benefits of beavers and their habitat, we should develop guidelines for managing beaver colonies on private land and promote the environmental benefits of beavers and their habitat [Objectives 4.1, 4.2]. These recommendations could be part of a publication available to landowners who wish to better manage beaver colonies residing on their properties. The publication could be in the form of a brochure or Game News article and would describe how to manage beaver populations for maximum longevity and beaver habitat for maximum wildlife use [Strategies 4.1.1, 4.2.1]. The environmental benefits of beaver habitat should be discussed as well as viewing recommendations in the publication [Strategy 4.2.2]. Where appropriate, we should consider adding beaver pond viewing and education as part of fall state game lands tours [Strategy 4.2.3].

Regulated beaver trapping is important not only for protecting private property and assuring public safety, but also for protecting and prolonging wetland habitat. We should strive to always permit regulated trapping of beavers in Pennsylvania [Objective 5.1] on an annual basis [Strategy 5.1.1]. Trapping provides many benefits to society as well as to beaver populations themselves.

In order to introduce youth to beaver trapping, we should investigate the possibility of establishing a youth-mentored trapping program [Strategy 5.1.2]. The assistance of the Pennsylvania Trappers Association would be necessary to help establish a core of volunteers willing to serve as trapping mentors. The program could be structured similar to existing youth hunting programs and would occur during established trapping seasons.

Plan implementation

The goals, objectives, and strategies of this management plan provide guidance and direction as we seek to fulfill our mission. A timetable for completion of objectives and supporting strategies is depicted in Appendix 6. Agency personnel from many organizational divisions will be required to help implement strategies and complete objectives. Their involvement in assisting to complete these tasks is also summarized in Appendix 6. Identified actions and research needs are listed by strategy in Table 13.

Table 13. Abbreviated actions and research needs required to meet management plan goals.

Strategy/ Objective number	Action or research need
1.1.1	Obtain general beaver population status information by continuing to conduct annual WCO furbearer surveys.
1.1.2	Monitor population levels within each WMU or physiographic unit by annually conducting a colony count using ground surveys.
1.2.1	Conduct mandatory training of all beaver survey participants to establish consistency in beaver sign identification and in following survey protocol.
1.2.2	Develop and incorporate criteria for determining colony type (single, pair, or family) into the beaver population survey.
1.3	Develop a model to monitor beaver population changes.
1.3.1	Determine basic reproductive parameters (litter size, age at first reproduction, reproductive rate) of beaver populations within each WMU or other defined unit.
1.3.2	Collect harvest mortality information specific to each age group or age class. Calculate average beaver colony size using the methods developed by Novak (1977) and Swenson et al. (1983).
1.3.3	Determine how bag limits, season length, trap distance from beaver structures, and number and type of trapping devices influence beaver harvest.
1.4	Develop a GIS-based habitat suitability model.
1.4.1	Identify and map suitable beaver habitat features necessary for beaver occupancy.
1.4.2	Identify unoccupied, suitable beaver habitat.
1.5	Evaluate the practice of beaver relocation for establishing colonies in new locations.
1.5.1	Determine survival and movement patterns of relocated beavers.
1.5.2	Assess the cost of trapping and transferring beavers.
1.5.3	Evaluate release site habitat characteristics, timing of release, and the age and sex of trap-and-transferred beavers in successful and unsuccessful population establishment attempts.
1.6.1	Integrate beaver habitat needs into our state game lands plans to benefit beaver colony establishment and long term food supply.
1.6.2	Transplant beavers from nuisance areas to suitable habitat for the purpose of establishing new colonies if ecologically and fiscally feasible.
1.6.3	Establish protected beaver colonies on selected state game lands to create population refuges from which range expansion can occur.
2.1	Evaluate the accuracy of estimating the beaver harvest from furtaker survey results
2.1.1	Establish a means of refining mail survey harvest estimates based on comparisons of actual harvests determined from mandatory tagging with harvest estimates from furtaker mail surveys during the same years.
2.2.1	Examine other options of estimating annual harvests including some sort of mandatory beaver harvest reporting.

Table 13 (cont.). Abbreviated actions and research needs required to meet management plan goals.

Strategy/ Objective number	Action or research need
2.3.1	Determine additional measures of harvest or population trend such as some form of catch per unit effort by adding trapper effort questions to the annual furtaker survey.
2.4.1	Review beaver season limit, trapping regulation descriptions, and beaver structure definitions in the Hunting and Trapping Digest to improve trapper understanding of these terms.
2.4.2	Develop definitions of beaver structures such as lodge, dam, and food cache.
3.1.1	Annually conduct the WCO furbearer questionnaire to continue to monitor the frequency of beaver damage complaints. Add questions to the survey regarding types of beaver complaints received in order to monitor any change in damage types
3.2.1	Conduct a survey to determine the public's knowledge of beavers, benefits of beaver habitat, and options for control as well as the public's desired beaver population level.
4.1.1	Prepare a Game News article or brochure describing the benefits of a beaver colony and how to manage it for maximum wildlife use.
4.1.2	Create a web page focusing on beaver life history and beaver habitat benefits.
4.2.1	Incorporate information about beaver ecology and how beaver habitat benefits other wildlife into agency educational materials.
5.1.1	Establish an annual trapping season for beavers to include the period of maximum pelt primeness.
5.1.2	Investigate the possibility of establishing a youth-mentored trapping program.
5.2.1	Establish interpretive wildlife viewing areas on state game lands that highlight the contributions of beaver engineering.

LITERATURE CITED

Aleksiuk, M. 1970*a*. The function of the tail as a fat storage depot in the beaver (*Castor canadensis*). Journal of Mammalogy. 51:145-148.

Aleksiuk, M. 1970*b*. The seasonal food regime of arctic beavers. Ecology 51:264-270.

Allen, A.W. 1982. Habitat suitability index models: beaver. U.S. Department of Interior, Fish and Wildlife Service, FWS/OBS-82/10.30.

Allred, M. 1986. Beaver behavior. Naturegraph Publications, Inc., Happy Camp, California, USA

Anonymous. 1942. The beaver in Pennsylvania. Educational Pamphlet No. 4. Pennsylvania Game Commission. Harrisburg, Pennsylvania, USA.

Anonymous. 2001. Wildlife crop damage manual. Ohio Dept. of Natural Resources, Division of Wildlife, Columbus, Ohio, USA.

Arner, D.H. 1963. Production of duck food in beaver ponds. Journal of Wildlife Management 27:76-81.

Arner, D.H., and J.C. Jones. 2009. Wildlife habitat management for special use areas. Mississippi State University, Mississippi State, Mississippi, USA.

Arner, D.H., and J.S. DuBose. 1982. The impact of beaver on the environment and economics in the southeastern United States. Proceedings of the 14th International Wildlife Congress 14:241-247.

Association of Fish and Wildlife Agencies. 2007*a*. Best management practices for trapping beaver in the United States. Furbearer resources technical work group, Washington, District of Columbia, USA.

Association of Fish and Wildlife Agencies. 2007*b*. Introduction: best management practices for trapping in the United States. Furbearer resources technical work group, Washington, District of Columbia, USA.

Bailey, T.N. 1981. Characteristics, trapping techniques, and views of trappers on a wildlife refuge in Alaska. Pages 1904-1918 *in* J.A. Chapman and D. Pursley, editors. Worldwide Furbearer Conference Proceedings. Frostburg, Maryland, USA.

Baker, B.W., and E.P. Hill. 2003. Beaver. pages 288-310 *in* G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition. Johns Hopkins University Press, Baltimore, Maryland, USA.

Baker, J.A., and P.M. Dwyer. 1987. Techniques for commercially harvesting furbearers. Pages 970-995 *in* M. Novak, J. Baker, M. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Beard, E.B. 1953. The importance of beaver in waterfowl management at the Seney National Wildlife Refuge. Journal of Wildlife Management 17:398-436.

Beer, J.R. 1955. Movements of tagged beaver. Journal of Wildlife Management 19:492-493.

Bergerud, A.T., and D.R. Miller. 1977. Population dynamics of Newfoundland beaver. Canadian Journal of Zoology 55:1480-1492.

Berghofer, C.B. 1961. Movement of beaver. Proceedings of the Annual Conference of Western Association of State Game and Fish Commissions 41:181-184.

Bishop, P., M. Brown, R. Cole, M. Ermer, R. Gotie, J. Lamendola, B. Penrod, S. Smith, and W. Sharick. 1992. Beaver Management in New York State: History and Specification of Future Program. New York State Department or Environmental Conservation Report.

Boddicker, M.L. 1981. Profiles of American trappers and trapping. Pages 1919-1949 *in* J.A. Chapman and D. Pursley, editors. Worldwide Furbearer Conference Proceedings. Frostburg, Maryland, USA.

Bosma, D. 2003. Regarding beaver. International Trapper 11:8-12.

Boyce, M.S. 1974. Beaver population ecology in interior Alaska. M.S. Thesis, Univ. Alaska, Fairbanks, Alaska, USA.

Boyce, M.S. 1981. Habitat ecology of an unexploited population of beavers in interior Alaska. Pages 155-186 *in* J.A. Chapman and D. Pursley, editors. Worldwide Furbearer Conference Proceedings. Frostburg, Maryland, USA.

Boyd, R.C., and M.J. Cegelski. 2008. Game take and furtaker surveys. Annual Job Report. Pennsylvania Game Commission, Harrisburg, Pennsylvania, USA.

Brenner, F.J. 1960. Life history and general ecology of the beaver (Castor Canadensis) in Crawford County, Pennsylvania. M.S. Thesis, The Pennsylvania State University, University Park, Pennsylvania, USA

Brenner, F.J. 1962. Foods consumed by beavers in Crawford County, Pennsylvania. Journal of Wildlife Management 26:104-107.

Brenner, F.J. 1964. Reproduction of the beaver in Crawford County, Pennsylvania. Journal of Wildlife Management 28:743-747.

Brooks, R.P. 1977. Induced sterility of the adult female beaver (*Castor canadensis*) and colony fecundity. M.S. Thesis, University of Massachusetts, Amherst, Massachusetts, USA.

Brooks, R.P., M.W. Fleming, and J.J. Kennelly. 1980. Beaver colony response to fertility control: evaluating a concept. Journal of Wildlife Management 44:568-575.

Brooks, R.P., D.A. Devlin, J.H. Hassinger, G.A. Hoover, and M.C. Brittingham. 1993. Wetlands and wildlife. The Pennsylvania State University, University Park, Pennsylvania, USA.

Bradt, G.W. 1938. A study of beaver colonies in Michigan. Journal of Mammalogy 19:139-162.

Bradt, G.W. 1939. Breeding habits of beaver. Journal of Mammalogy 20:486-489.

Bryce, G. 1904. The remarkable history of the Hudson Bay Company. Reprinted in 1968 by Burt Franklin, New York, New York, USA.

Buech, R.R. 1984. Ontogeny and diurnal cycle of fecal reingestion in the North American beaver (*Castor canadensis*). Journal of Mammalogy 65:347-350.

Cole, R.W. 1970. Pharyngeal and lingual adaptations in the beaver. Journal of Mammalogy 51:424-425.

Collins, T.C. 1976. Population characteristics and habitat relationships of beavers, *Castor canadensis*, in northwest Wyoming. Ph.D. Dissertation, University of Wyoming, Laramie, Wyoming, USA.

Cook, D.B. 1943. History of a beaver colony. Journal of Mammalogy 24:12-18.

Cook, A.H., and E.R. Maunton. 1954. A study of criteria for estimating the age of beavers. New York Fish and Game Journal 1:27-46.

Cutright, W.J., and T. McKean. 1979. Countercurrent blood vessel arrangement in beaver (*Castor canadensis*). Journal of Morphology 161:169-176.

Davidson, W.R. 2006. Field manual of wildlife diseases in the southeastern United States. Southeastern Cooperative Wildlife Disease Study, Third edition, University of Georgia, Athens, Georgia, USA.

de Almeida, M.H. 1987. Nuisance furbearer damage control in urban and suburban areas. Pages 996-1006 *in* M. Novak, J. Baker, M. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Deems, E.F., Jr., and D. Pursley. 1978. North American furbearers, their management, research and harvest status in 1976. International Association of Fish and Wildlife Agencies, USA.

Deems, E.F., Jr., and D. Pursley. 1983. North American furbearers: a contemporary reference. First edition. International Association of Fish and Wildlife Agencies, USA.

Denney, R.N. 1952. A summary of North American beaver management, 1946-1948. Current Report 28. Colorado Game and Fish Department, Denver, Colorado, USA.

Doboszynska, T., and W. Zurowski. 1983. Reproduction of the European beaver. Acta Zoologica Fennica 174:123-126.

Doutt, J.K., C.A. Heppenstall, and J.E. Guilday. 1977. Mammals of Pennsylvania. Pennsylvania Game Commission, Harrisburg, Pennsylvania, USA.

Dubuc, L.J., W.B. Krohn, and R.B. Owen, Jr. 1990. Predicting occurrence of river otters by habitat on Mount Desert Island, Maine. Journal of Wildlife Management 54:594-599.

Erickson, D.W. 1981. Furbearer harvest mechanics: an examination of variables influencing fur harvests in Missouri. Pages 1469-1491 *in* J.A. Chapman and D. Pursley, editors. Worldwide Furbearer Conference Proceedings. Frostburg, Maryland, USA.

Erickson, D.W., and F.W. Sampson. 1978. Impact of market dynamics on Missouri's furbearer harvest system. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 32:17-29.

Fayer, R., M. Santin, J.M. Trout, S. DeStefano, K. Koenen, and T. Kaur. 2006. Prevalence of microsporidia, *Cryptosporidium* spp., and *Giardia* spp. in beavers (*Castor canadensis*) in Massachusetts. Journal of Zoo and Wildlife Medicine 37(4):492-497.

Flyger, V., D.L. Leedy, and T.M. Franklin. 1983. Wildlife damage control in eastern cities and suburbs. Proceedings of the Eastern Wildlife Damage Control Conference 1:27-32.

Friley, C.E., Jr. 1949. Use of the baculum in age determination of Michigan beaver. Journal of Mammalogy 30:261-265.

Gallo-Reynoso, J., G. Suarez-Gracida, H. Cebrera-Santiago, E. Coria-Galindo, J. Egido-Villarreal, and L.C. Ortiz. 2002. Status of beavers (*Castor canadensis frondator*) in Rio Bavispe, Sonora, Mexico. The Southwestern Naturalist 47:501-504.

Gibson, G.G. 1957. A study of beaver colonies in southern Algonquin Park, Ontario, with particular reference to the available food. M.A. Thesis, University of Toronto, Ontario, Canada.

Gilbert, E.F., and N. Gofton. 1982. Heart rate values for beaver, mink and muskrat. Comparative Biochemistry and Physiology. Part A: Physiology. 73(2):249-251.

Gleason, J.S., R.A. Hoffman, and J.M. Wendland. 2005. Beavers, *Castor canadensis*, feeding on salmon carcasses: opportunistic use of a seasonally superabundant food source. Canada Field Naturalist. 119:591-593.

Gordon, K.L., and D.H. Arner. 1976. Preliminary study using chemosterilants for control of nuisance beaver. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 30:463-465.

Grover, A.M., and G.A. Baldassarre. 1995. Bird species richness within beaver ponds in southcentral New York. Wetlands 15:108-118.

Gunson, J.R. 1970. Dynamics of the beaver of Saskatchewan's northern forest. M.S. Thesis, University of Alberta, Edmonton, Canada.

Hakala, J.B. 1952. The life history and general ecology of the beaver (*Castor canadensis* Kuhl) in interior Alaska. M.S. Thesis, University of Alaska, Fairbanks, Alaska, USA.

Hall, E.R. 1981. The mammals of North America. Second edition, John Wiley, New York, New York, USA.

Hall, G.E., and M.E. Obbard. 1987. Pelt preparation. Pages 842-861 *in* M. Novak, J. Baker, M. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Harper, W.R. 1968. Chemosterilant assessment for beaver. M.S. Thesis, Colorado State University, Fort Collins, Colorado, USA.

Hay, K.G. 1958. Beaver census methods in the Rocky Mountain region. Journal of Wildlife Management 22:395-402.

Hayden, A.H. 1990. The age structure of the beaver harvest. Annual Job Report. Pennsylvania Game Commission, Harrisburg, Pennsylvania, USA.

Henry, D.B., and T.A. Bookhout. 1969. Productivity of beavers in northeastern Ohio. Journal of Wildlife Management 33:927-932.

Hepp, G.R., and J. D. Hair. 1977. Wood duck brood mobility and utilization of beaver pond habitats. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 31:216-225.

Hibbard, E.A. 1958. Movements of beaver transplanted in North Dakota. Journal of Wildlife Management 22:209-211.

Hilfiker, E.L. 1991. Beavers: water, wildlife and history. Windswept Press, Interlaken, New York, USA.

Hill, E.P. 1976. Control methods for nuisance beaver in the southeastern United States. Pages 85-98 *in* Proceedings of the Seventh Vertebrate Pest Control Conference. University of California, Davis, California, USA.

Hill, E.P. 1982. Beaver. pages 256-281 *in* J.A. Chapman and G.A. Feldhamer, editors. Wild mammals of North America: biology, management, and economics. First edition, Johns Hopkins Univ. Press, Baltimore, Maryland, USA.

Henry, D.B., and T.A. Bookhout. 1969. Productivity of beavers in northeastern Ohio. Journal of Wildlife Management 33:927-932.

Hodgdon, H.E., and R.A. Lancia. 1983. Behavior of the North American beaver, *Castor canadensis*. Acta Zoologica Fennica 174:99-103.

Huey, W.S. 1956. New Mexico beaver management. Bulletin 4. New Mexico Department of Game and Fish. Santa Fe, New Mexico, USA.

Irving, L., and M.D. Orr. 1935. The diving habits of the beaver. Science 82:569.

Ives, R.L. 1942. The beaver-meadow complex. Journal of Geomorphology 5:191-203.

Jenkins, S.H. 1975. Food selection by beavers: a multidimensional contingency table analysis. Oecologia 21:157-173.

Jenkins, S.H. 1981. Problems, progress, and prospects in studies of food selection by beaver. Pages 559-579 *in* J.A. Chapman and D. Pursley, editors. Worldwide Furbearer Conference Proceedings. Frostburg, Maryland, USA.

Johnston, C.A., and R.J. Naiman. 1987. Boundary dynamics at the aquatic-terrestrial interface: the influence of beaver and geomorphology. Landscape Ecology 1:47-57.

Jones, J.K., Jr., and R.W. Manning. 1992. Illustrated key to skulls of genera of North American land mammals. Texas Tech Univ. Press, Lubbock, Texas, USA.

Knudsen, G.L. 1953. Beaver die-off. Wisconsin Conservation Bulletin 16:20-23.

Knudsen, G.L. 1962. Relationship of beaver to forests, trout and wildlife in Wisconsin. Technical Bulletin 25, Wisconsin Conservation Department 52 pp.

Knudsen, G.L., and J.B. Hale. 1965. Movements of transplanted beavers in Wisconsin. Journal of Wildlife Management 29:685-688.

Kosack, J. 1995. The Pennsylvania Game Commission 1895-1995, 100 years of wildlife conservation. Pennsylvania Game Commission, Harrisburg, Pennsylvania, USA.

Labzoffsky, N.A., and J.A.F. Sprent. 1952. Tularemia among beaver and muskrat in Ontario. Canadian Journal of Medical Sciences 30:250-255.

Langlois, S.A. 1999. A comparison of survey methods to estimate beaver (*Castor canadensis*) colony densities in Massachusetts. M.S. Thesis, University of Massachusetts, Amherst, Massachusetts, USA.

Libby, W.L. 1957. Observations on beaver movements in Alaska. Journal of Mammalogy 38:269.

Maringer, A., and L. Slotta-Bachmayr. 2006. A GIS-based habitat-suitability model as a tool for the management of beavers *Castor fiber*. Acta Theriologica 51:373-382.

Marshall, A.D. 1981. Characteristics of Georgia trappers. Pages 2004-2008 *in* J.A. Chapman and D. Pursley, editors. Worldwide Furbearer Conference Proceedings. Frostburg, Maryland, USA.

McDowell, D.M., and R.J. Naiman. 1986. Structure and function of a benthic invertebrate stream community as influenced by beaver (*Castor canadensis*). Oecologia 68: 481-489.

McNeely, R. 1995. Missouri's beaver: a guide to management, nuisance prevention and damage control. Missouri Conservation Commission, Jefferson City, Missouri, USA.

Miller, F.W. 1948. Early breeding of Texas beaver. Journal of Mammalogy 29:419.

Miller, J.E. 1983. Control of beaver damage. Proceedings of the Eastern Wildlife Damage Control Conference 1:177-183.

Miller, J.E., and G.K. Yarrow. 1994. Beavers. Pages B1-B11 *in* S.E. Hygnstrom, R.M. Timm, and G.M. Larson, editors. Prevention and control of wildlife damage. Univ. of Nebraska Cooperative Extension, Great Plains Agricultural Council–Wildlife Committee, USDA-APHIS-Animal Damage Control. University of Nebraska, Lincoln, Nebraska, USA.

Naiman, R.J., C.A. Johnston, and J.C. Kelley. 1988. Alteration of North American streams by beaver: the structure and dynamics of streams are changing as beaver recolonize their historic habitat. Bioscience 38:753-762.

Naiman, R.J., and J.M. Melillo. 1984. Nitrogen budget of a subarctic stream altered by beaver (*Castor canadensis*). Oecologia 62:150-155.

Naiman, R.J., J.M. Melillo, and J.E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (*Castor canadensis*). Ecology 67:1254-1269.

Novak, M. 1977. Determining the average size and composition of beaver families. Journal of Wildlife Management 41:751-754.

Novak, M. 1987. Beaver. Pages 283-312 *in* M. Novak, J. Baker, M. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

New York State Department of Environmental Conservation. 1996. Beaver damage control techniques manual. Bureau of Wildlife, Albany, USA.

Obbard, M.E. 1987. Fur grading and pelt identification. Pages 717-826 *in* M. Novak, J. Baker, M. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Osborn, D.J. 1955. Techniques of sexing beaver, *Castor canadensis*. Journal of Mammalogy 36:141-142.

Parsons, G.R., and M.K. Brown. 1978. An assessment of aerial photograph interpretation for recognizing potential beaver colony sites. Transactions of the Northeast Section of The Wildlife Society. 35:181-184.

Payne, N.F. 1975. Trapline management and population biology of Newfoundland beaver. Ph.D. Dissertation, Utah State University, Logan, Utah, USA.

Payne, N.F. 1982. Colony size, age, and sex structure of Newfoundland beaver. Journal of Wildlife Management 46:655-661.

Payne, N.F. 1984*a*. Reproductive rates of beavers in Newfoundland. Journal of Wildlife Management 48:912-917.

Payne, N.F. 1984*b*. Mortality rates of beavers in Newfoundland. Journal of Wildlife Management 48:117-126.

Peterson, S. 2000. Beaver sealing: why do we still do it? American Trapper 40(1):36-41.

Potvin, F., L. Breton, C. Pilon, and M. Macquart. 1992. Impact of an experimental wolf reduction on beaver in Papineau-Labelle Reserve, Quebec. Canadian Journal of Zoology 70:180-183.

Prosser, D. 1998. Avian use of different successional stage beaver ponds in Pennsylvania. M.S. Thesis, Pennsylvania State University, University Park, Pennsylvania, USA.

Reese, K.P., and J.D. Hair. 1976. Avian species diversity in relation to beaver pond habitats in the Piedmont region of South Carolina. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 30:437-447.

Renouf, R.N. 1972. Waterfowl utilization of beaver ponds in New Brunswick. Journal of Wildlife Management 36:740-744.

Rhoads, S.N. 1903. The mammals of Pennsylvania and New Jersey. Privately published, Philadelphia, Pennsylvania, USA.

Ringelman, J.K. 1991. Managing beaver to benefit waterfowl. U.S. Fish Wildl. Serv. Fish Wildl. Leaflet No. 13.4.7.

Roberts, T.H., and D.H. Arner. 1984. Food habits of beaver in east-central Mississippi. Journal of Wildlife Management. 48:1414-1419.

Rue, L.E. III. 1964. The world of the beaver. J.B. Lippincott Co., Philadelphia, Pennsylvania, USA.

San Julian, G.J. 1983. The need for urban animal control. Proceedings of the Eastern Wildlife Damage Control Conference 1:313-314.

Samuel, D.E., and L.L. Bammel. 1981. Attitudes and characteristics of independent trappers and National Trappers' Association members in West Virginia. Pages 2021-2036 *in* J.A. Chapman and D. Pursley, editors. Worldwide Furbearer Conference Proceedings. Frostburg, Maryland, USA.

Schipper, S.S. 1987. Garment manufacturing. Pages 878-888 *in* M. Novak, J. Baker, M. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Semyonoff, B.T. 1951. The river beaver in Archangel Province. Pages 5-45 *in* Russian Game Report. Volume 1. Canadian Department of North. Affairs and Natural Resources, Ottawa, Ontario (translated from Russian).

Seton, E.T. 1929. Lives of game animals. Vol. 4, Part 2, Rodents, etc. Doubleday, Doran, Garden City, New York, USA.

Shadle, A.R. 1930. An unusual case of parturition in beaver. Journal of Mammalogy 11:483-485.

Shelton, P.C. 1966. Ecological studies of beavers, wolves, and moose in Isle Royal National Park, Michigan. Ph.D. Dissertation, Purdue University, Lafayette, Indiana, USA.

Southwick Associates. 1994. State and provincial beaver status survey. Report for Fur Resources Committee, Int. Assoc. Fish Wildl. Agencies. Fernandina Beach, Florida, USA.

Stains, H.J. 1979. Primeness in North American furbearers. Wildlife Society Bulletin 7:120-124.

Sterba, J.P. 2002. Leave it to beaver. The Wall Street Journal 239(99):A1,A12-13.

Svendsen, G.E. 1978. Castor and anal glands of the beaver (*Castor canadensis*). Journal of Mammalogy 59:618-620.

Swank, W.G., and F.A. Glover. 1948. Beaver censusing by airplane. Journal of Wildlife Management. 12:214.

Swenson, J.E., S.J. Knapp, P.R. Martin, and T.C. Hinz. 1983. Reliability of aerial cache surveys to monitor beaver population trends on prairie rivers in Montana. Journal of Wildlife Management 47:697-703.

Vaughan, T.A. 1978. Mammalogy. W.B. Saunders Company, Philadelphia, Pennsylvania, USA.

Vispo, C., and I.D. Hume. 1995. The digestive tract and digestive function in the North American beaver. Canadian Journal of Zoology 73:967-974.

Walro, J.M. and G.E. Svendsen. 1982. Castor sacs and anal glands of the North American beaver (*Castor canadensis*): their histology, development, and relationship to scent communication. Journal of Chemical Ecology 8:809-819.

Weaver, K.M. 1986. Dispersal patterns of subadult beavers in Mississippi as determined by implant radio-telemetry. M.S. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Weaver, K.M., D.H. Arner, C.E. Mason, and J.J. Hartley. 1985. A guide to the use of snares for beaver capture. Southern Journal of Applied Forestry 9(3):141-146.

Wheatley, M. 1997. Beaver, *Castor canadensis*, home range size and patterns of use in the taiga of southeastern Manitoba: III. Habitat variation. Canadian Field-Naturalist 111:204-210.

Wigley, T.B., Jr., T.H. Roberts, and D.H. Arner. 1983. Reproductive characteristics of beaver in Mississippi. Journal of Wildlife Management 47:1172-1177.

Wilde, S.A., C.T. Youngberg, and J.H. Hovind. 1950. Changes in composition of ground water, soil fertility, and forest growth produced by the construction and removal of beaver dams. Journal of Wildlife Management 14:123-127.

Williams, R.M. 1965. Beaver habitat and management. Idaho Wildlife Review 17(4):3-7.

Wilsson, L. 1968. My beaver colony. Doubleday & Co., New York, New York, USA.

Wilsson, L. 1971. Observations and experiments on the ethology of the European beaver (*Castor fiber* L.). Viltrevy 8:115-266.

Woo, P.T.K., and W.B. Paterson. 1986. *Giardia lamblia* in children in day-care centers in southern Ontario, Canada, and susceptibility of animals to *Giardia lamblia*. Trans. R. Soc. Med. Hyg. 80:56-59.

Woodward, D.K. 1977. Status and ecology of the beaver (*Castor canadensis carolinensis*) in South Carolina with emphasis on the Piedmont. M.S. Thesis, Clemson University, Clemson, South Carolina, USA.

Worthy, G.A.J., J. Rose, and F. Stormshak. 1987. Anatomy and physiology of fur growth: the pelage priming process. Pages 827-841 *in* M. Novak, J. Baker, M. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Yeager, L.E., and W.H. Rutherford. 1957. An ecological basis for beaver management in the rocky mountain region. Transactions of North American Wildlife Conference 22:269-300.

APPENDIX 1. Beaver regulation history in Pennsylvania. Data were omitted for years where no significant changes occurred from the previous year or where no information was available.

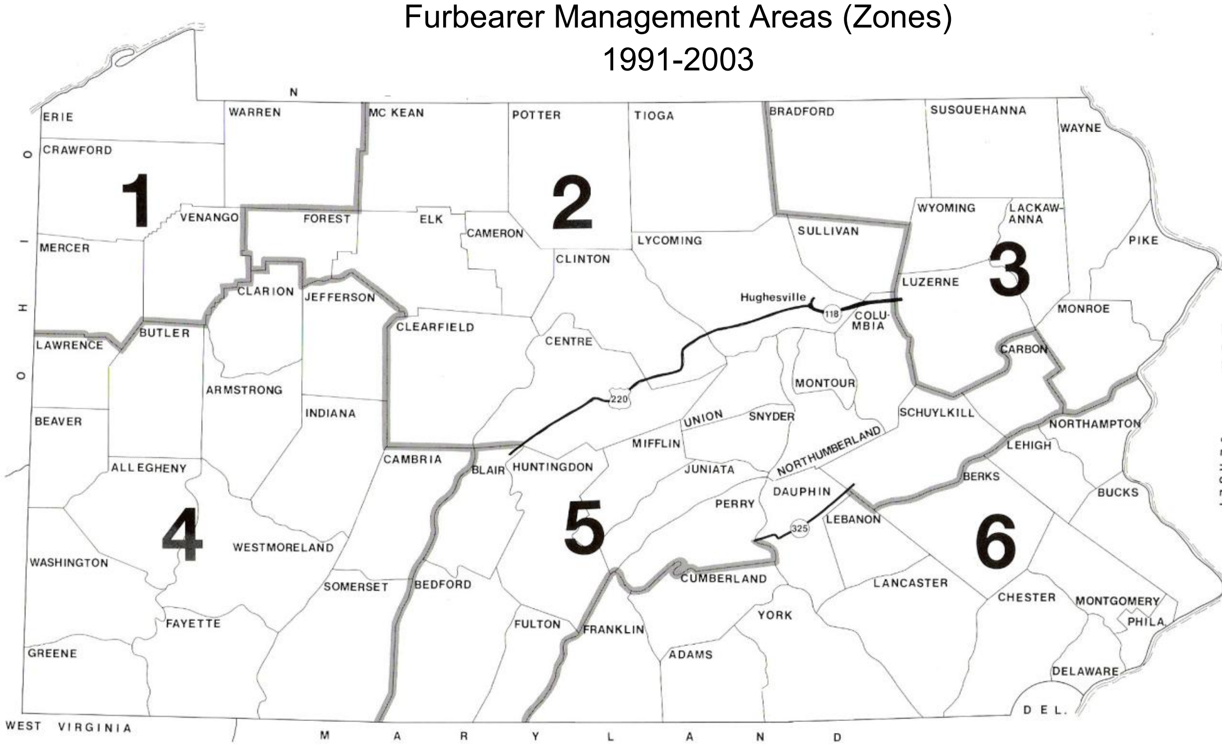
Year	Season Dates	Bag Limit (daily/season)	Trap Types	Trap Location Restriction	Tagging
1934	1 Mar-10 Apr	6/6 statewide	10 traps; beavers could be taken by traps only and not shot.		Mandatory pelt tagging
1935	Closed season				
1936	16-31 Mar	Unknown bag limit – statewide season			
1937	1-15 Mar	Unknown bag limit – statewide season			
1938	15-28 Feb	Unknown bag limit in 18 counties			
1939	15-28 Feb	Unknown bag limit in 8 counties			
1940	15-31 Jan	Unknown bag limit in 20 counties			
1941	1-15 Mar	Unknown bag limit in 28 counties			
1944				Sets prohibited 15 feet from the waterline of any beaver house.	
1946				Sets prohibited 25 feet from the waterline of any beaver house.	
1959		5/5		Sets prohibited within 25 feet of any beaver house or dam.	
1960	10 Feb-18 Mar	7/7	"a" body-gripping trap may be used underwater.		
1961	9 Feb-10 Mar	4/4, except 7/7 in some counties			
1962		3/3, except 6/6 in some counties			
1969			10 total traps, 2 can be body-gripping.		
1970	6 Feb-7 Mar	3/3, except … 6/6			
1976	12 Feb-12 Mar				
1977	11 Feb-20 Mar	3/3			

Year	Season Dates	Bag Limit (daily/season)	Trap Types	Trap Location Restriction	Tagging
1981	13 Feb-14 Mar	3/3, except Crawford, Erie, Bradford, Susq, Pike, Sullivan, Wayne counties: 5/5			
1982	12 Feb-13 Mar	3/3, except Brad, Susq, Wayne, Monroe, Pike, Sulliv, Erie, Crawford counties: 5/5			
1983	26 Dec-29 Jan	5/5			
1984	26 Dec-26 Jan 2-16 Mar	6/6			
1986	26 Dec-14 Mar	6/6, except Wayne Co.: 12/12			
1988	21 Dec-5 Mar	6/6, except Pike, Susq, Wayne counties: 12/12	10 total traps, 2 can be body-gripping. 10 body-gripping allowed in Pike, Susq, Wayne Cos.		
1990	19 Dec-3 Mar	6/6, except Brad, Susq, Wayne counties: 6/24			
1991	21 Dec-20 Jan	**Furbearer Management Areas (Zones) created** Zones 1-3: 10/10 Zones 4-6: 6/6 Brad, Susq, Wayne counties: 10/40			
1994	17 Dec-22 Jan	Zones 1-2: 10/20 Zone 3-4: 10/10 Zone 5-6: 6/6 Brad, Susq, Wayne counties: 10/40			
1995	9 Dec-21 Jan Extension: 2-24 Mar Zones 1-3,6.	Zones 1-3: 10/40 Zones 4-5: 10/10 Zone 6: 6/6			
1996	14 Dec-26 Jan	Zones 1-3: 10/20 Zone 4-5: 10/10 Zone 6: 6/6 Brad, Susq, Wayne counties: 10/40			

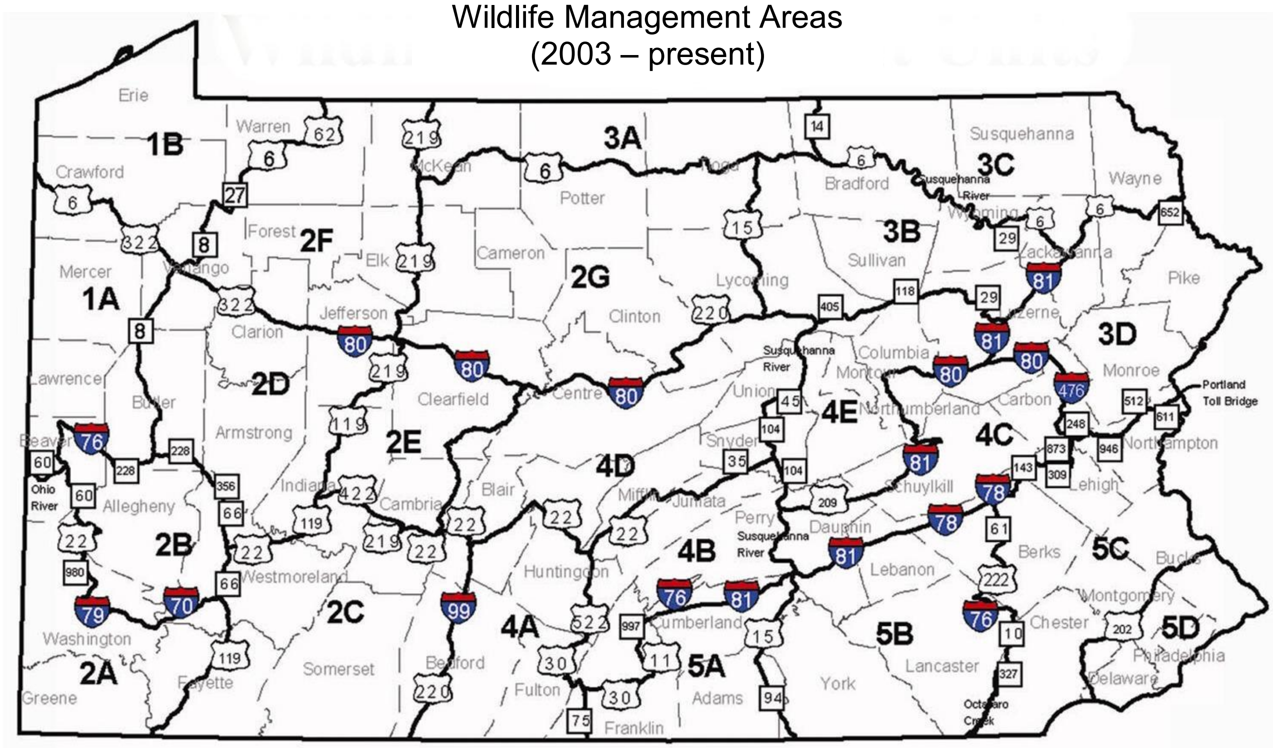
Year	Season Dates	Bag Limit (daily/season)	Trap Types	Trap Location Restriction	Tagging
1998	26 Dec-15 Mar	Zones 1-3: 10/20 Zone 4-5: 10/10 Zone 6: 6/6 Brad, Susq, Wayne, McKean, Potter, Tioga Cos.: 10/40	Beaver snare legal statewide. Limited to 10 total trapping devices.		
2000	26 Dec-31 Mar				
2001		Zones 1-2: 20/20 Zone 3: 20/40 Zones 4-5: 10/10 Zone 6: 6/6 Brad, Susq, Wayne, McKean, Potter, Tioga counties: 20/40	20 total devices allowed. Up to 10 traps; up to 20 snares.	No restriction on location of sets near lodges or dams within **Zone 3**.	Pelt tagging fee (50¢) removed.
2003		**Wildlife Management Units created** 1A-B, 2F, 2G: 20/20 3A-D: 20/40 2A-E,4A-E: 10/10 5A-D: 6/6	10 body gripping traps allowed in **WMUs 3A-D**.	No restriction on location of sets near lodges or dams within **WMUs 3B-D**.	
2004		Same			Pelt tagging not required.
2005		2F, 2G: 20/20 1A-B, 3A-D: 20/40 2A-E, 4A-E: 10/10 5A-D: 6/6			
2006		2E-G: 20/20 1A-B, 3A-D: 20/40 2A-D, 4A-E, 5A-D: 10/10			
2010 (current regula-tions)	26 Dec-31 Mar	2E-G: 20/20 1A-B, 3A-D: 20/40 2A-D, 4A-E, 5A-D: 10/10	20 total devices allowed. Up to 10 traps; up to 20 snares. 10 body-gripping traps allowed in **WMUs 1B, 3A-D**.	No restriction on location of sets near lodges or dams within **WMUs 3B-D**.	Pelt tagging not required.

APPENDIX 2. Furbearer management areas and current wildlife management units used to regulate beaver harvest and manage populations.

Furbearer Management Areas (Zones)
1991-2003



Wildlife Management Areas
(2003 – present)



APPENDIX 3. Furbearer questionnaire mailed annually to wildlife conservation officers.

2008-2009 Furbearer Questionnaire

All questions pertain to furbearer information within your district during May 2008 to April 2009. If you are new to this district or cannot answer these questions, please submit this form anyway (leaving unknown answers blank) or forward it to the WCO who previously occupied or covered your district. Please do not answer "many" or "several" to questions asking "How many?" Give us your best estimates. **Please note that these types of questions will be asked annually.**

Instructions: Click on the **blue underline** to enter text. Click on the **check box** (☐) to select or deselect that response. Press **Tab** to advance.

District No. __________ WCO Name ___________________

1. How many **beaver** complaints were serviced in your district? _____

2. How would you describe **beaver** populations in your district?
   Established population ... ☐ increasing, ☐ decreasing, ☐stable
   Population not established … ☐ **not** well established, ☐ nonexistent

3. Could you locate and accurately count all known **beaver colonies** within your district?
   ☐ Yes ☐ No, they are too numerous

4. How many **river otters** were accidentally caught by trappers within your district? _____

5. How would you describe **river otter** populations in your district?
   Established population ... ☐increasing, ☐decreasing, ☐stable
   Population not established … ☐**not** well established, ☐nonexistent

6. How many reliable reports of **fishers** have you received in your district? _____

7. How many **fishers** were accidentally caught by trappers in your district? _____

8. How would you describe **fisher** populations in your district?
   Established population ... ☐increasing, ☐decreasing, ☐stable
   Population not established … ☐**not** well established, ☐nonexistent

9. How would you describe **bobcat** populations in your district?
   Established population ... ☐increasing, ☐decreasing, ☐ stable
   Population not established … ☐**not** well established, ☐nonexistent

10. Did you receive any **coyote** related complaints during this period? ☐Yes ☐ No

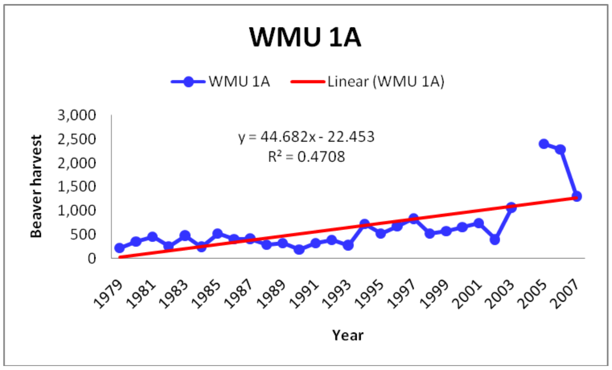
If you received coyote complaints, please record the type and number of complaints and animals killed. Omit any complaints that the Bureau of Dog Law Enforcement (PA Dept of Agriculture) serviced.

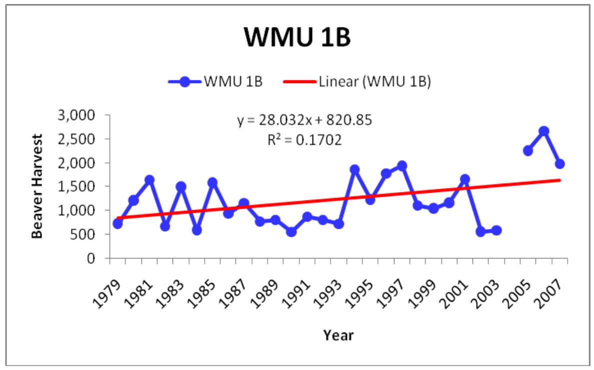
Number of Coyote **Complaints**:		Number of **Animals Killed** by Coyotes:	
_____	Cattle	_____	Cows
_____	Sheep	_____	Calves
_____	Goats	_____	Sheep/Lambs
_____	Poultry/Waterfowl	_____	Goats
_____	Attacked Dogs	_____	Poultry/Waterfowl
_____	Attacked Cats	_____	Dogs
_____	Afraid of Coyotes	_____	Cats
_____	Chased/Attacked Deer	_____	Rabbits
_____	Chased/Attacked Wild Turkey	_____	Deer
_____	Other _____	_____	Other _____

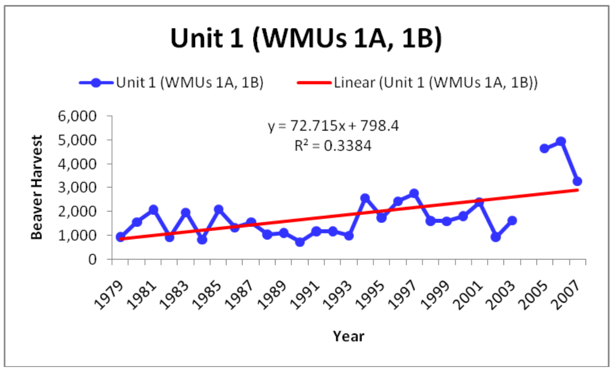
Thank you for your cooperation and assistance!

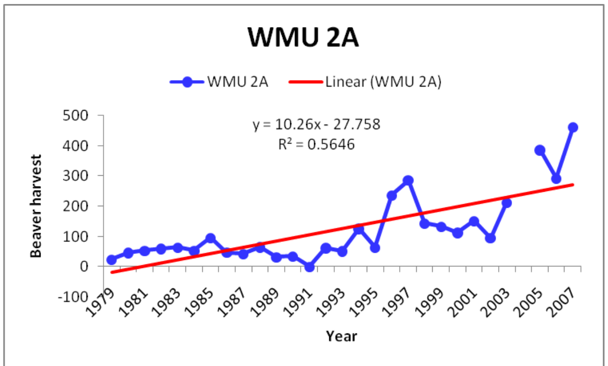
Please return this questionnaire to your regional director and regional wildlife management supervisor as an e-mail attachment.

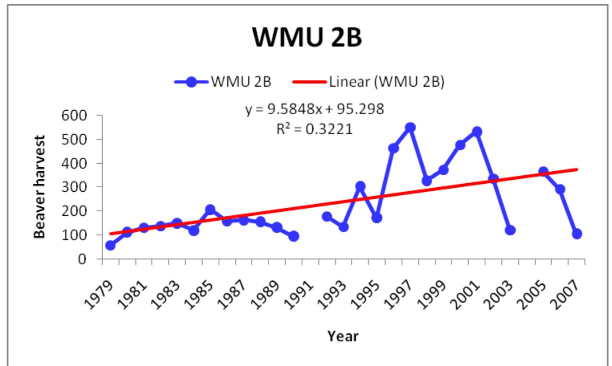
APPENDIX 4. Beaver harvest and trend within each wildlife management unit and physiographic unit (WMU group) during 1979-2007. The beaver harvest was not estimated in 2004.

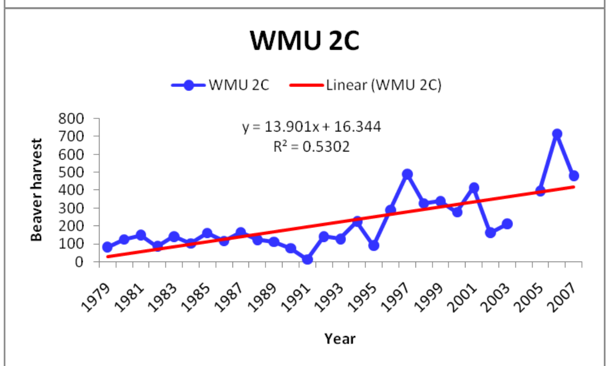


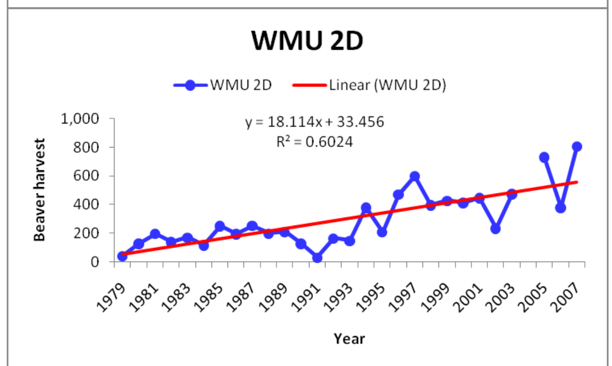


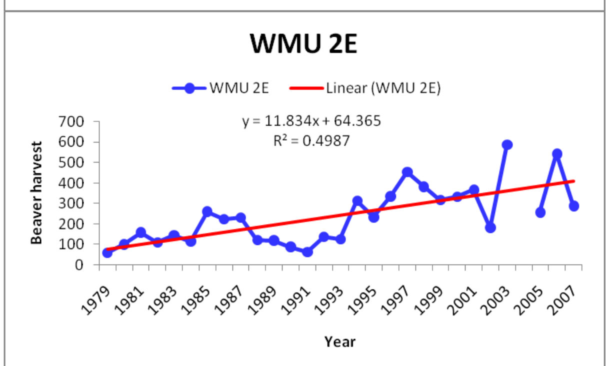


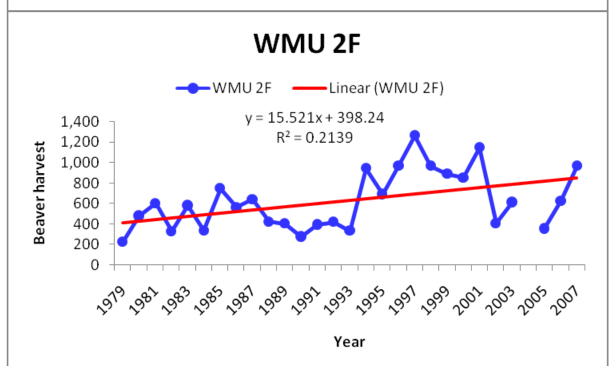

WMU 2A
WMU 2A
Linear (WMU 2A)
y = 10.26x - 27.758
R² = 0.5646
Beaver harvest
Year

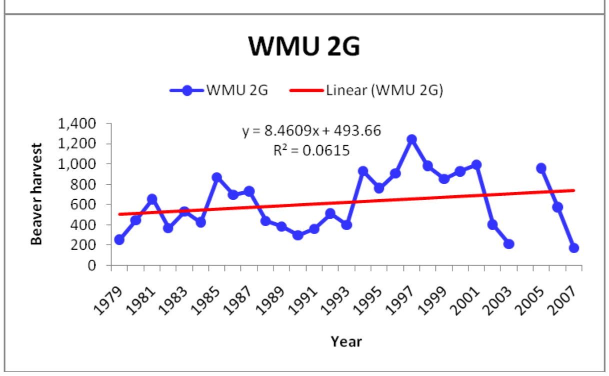

WMU 2B
WMU 2B
Linear (WMU 2B)
y = 9.5848x + 95.298
R² = 0.3221
Beaver harvest
Year

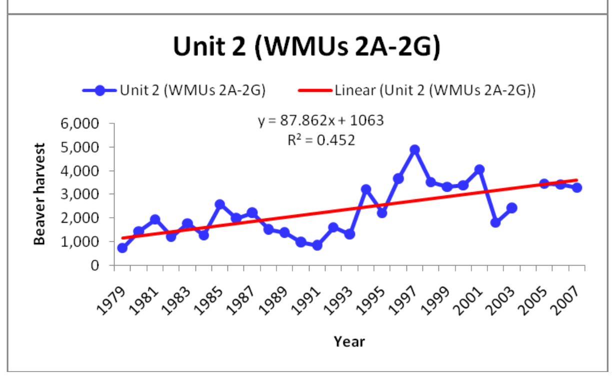

WMU 2C
WMU 2C
Linear (WMU 2C)
y = 13.901x + 16.344
R² = 0.5302
Beaver harvest
Year

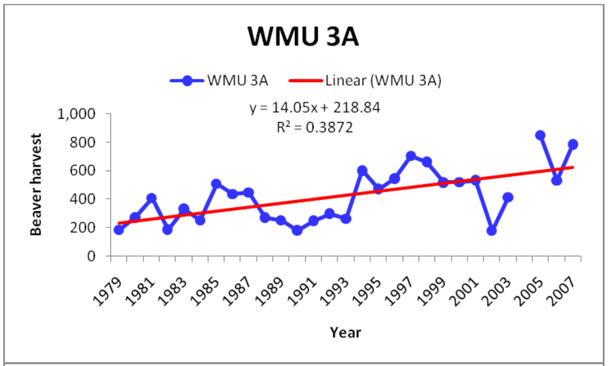

WMU 2D
WMU 2D
Linear (WMU 2D)
y = 18.114x + 33.456
R² = 0.6024
Beaver harvest
Year

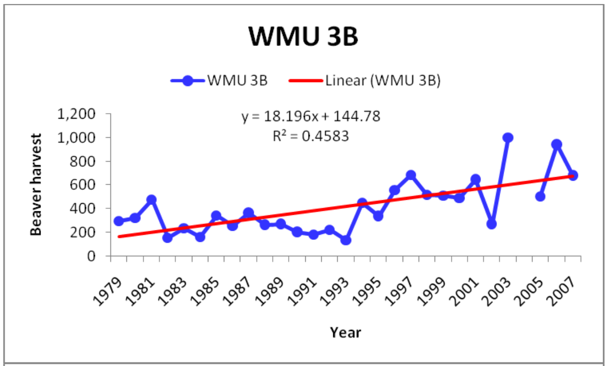

WMU 2E
WMU 2E
Linear (WMU 2E)
y = 11.834x + 64.365
R² = 0.4987
Beaver harvest
Year

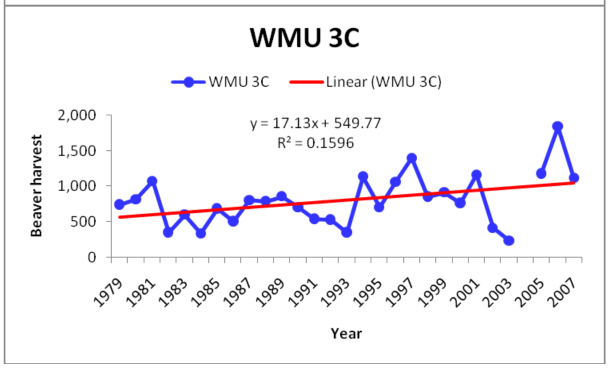

WMU 2F
WMU 2F
Linear (WMU 2F)
y = 15.521x + 398.24
R² = 0.2139
Beaver harvest
Year

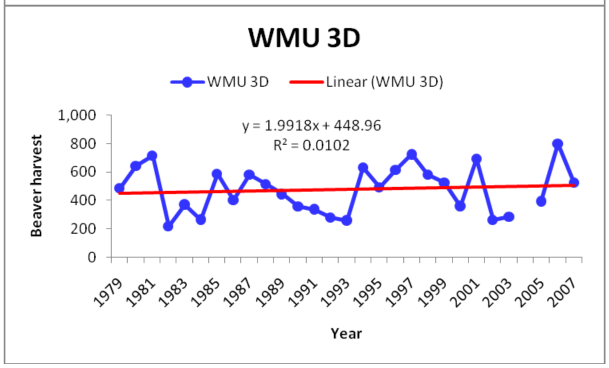

WMU 2G
WMU 2G
Linear (WMU 2G)
y = 8.4609x + 493.66
R² = 0.0615
Beaver harvest
Year

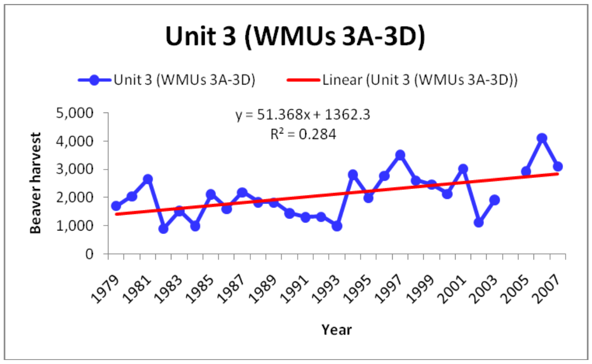

Unit 2 (WMUs 2A-2G)
Unit 2 (WMUs 2A-2G)
Linear (Unit 2 (WMUs 2A-2G))
y = 87.862x + 1063
R² = 0.452
Beaver harvest
Year

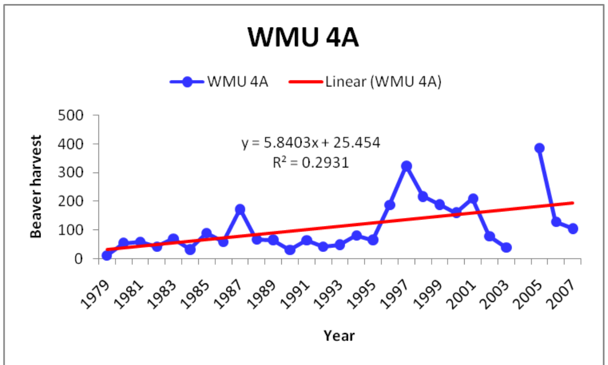

WMU 3A
WMU 3A
Linear (WMU 3A)
y = 14.05x + 218.84
R² = 0.3872
Beaver harvest
Year

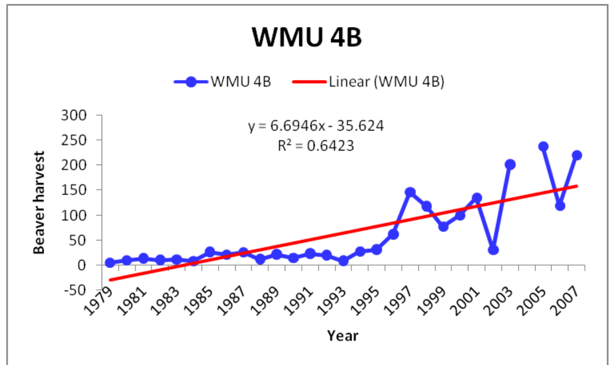

WMU 3B
WMU 3B
Linear (WMU 3B)
y = 18.196x + 144.78
R² = 0.4583
Beaver harvest
Year

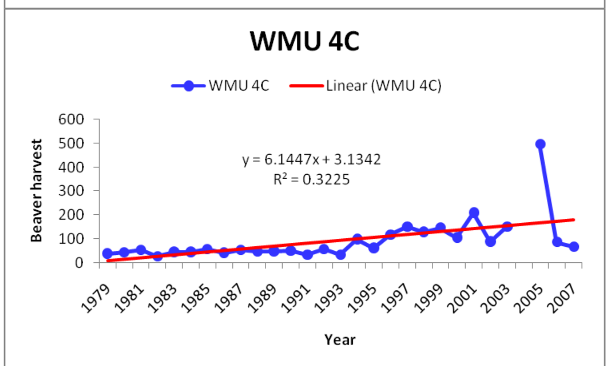

WMU 3C
WMU 3C
Linear (WMU 3C)
y = 17.13x + 549.77
R² = 0.1596
Beaver harvest
Year

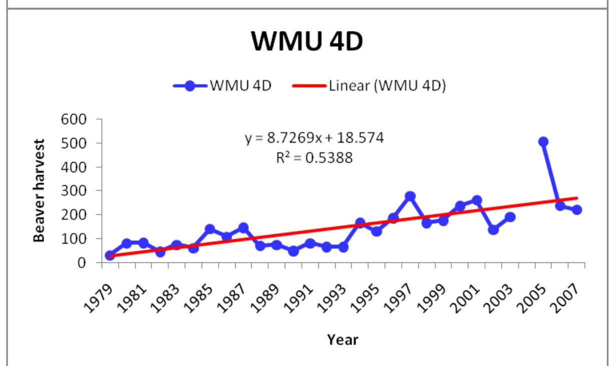

WMU 3D
WMU 3D
Linear (WMU 3D)
y = 1.9918x + 448.96
R² = 0.0102
Beaver harvest
Year

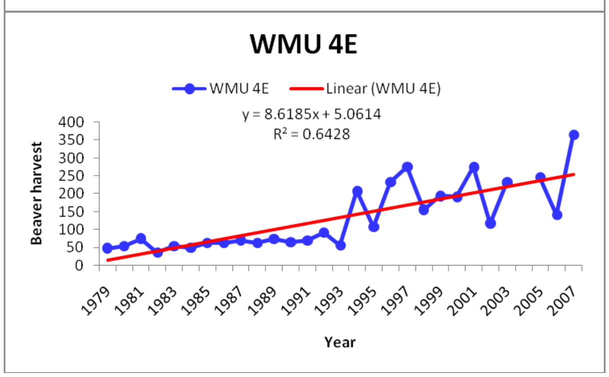

Unit 3 (WMUs 3A-3D)
Unit 3 (WMUs 3A-3D)
Linear (Unit 3 (WMUs 3A-3D))
y = 51.368x + 1362.3
R² = 0.284
Beaver harvest
Year

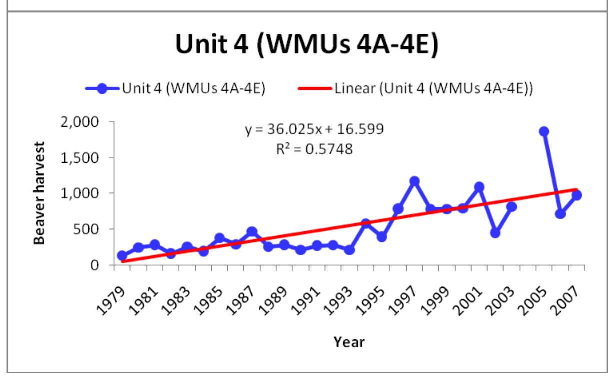

WMU 4A
WMU 4A
Linear (WMU 4A)
y = 5.8403x + 25.454
R² = 0.2931
Beaver harvest
Year

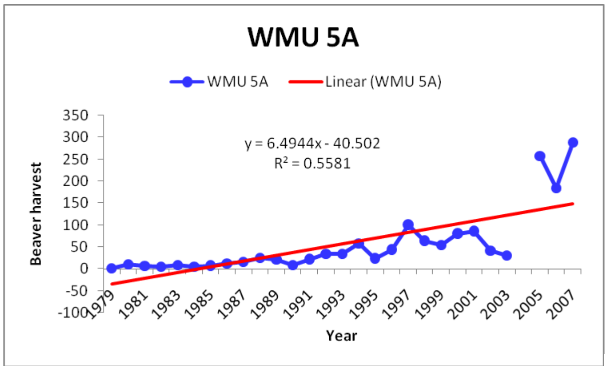

WMU 4B
WMU 4B
Linear (WMU 4B)
y = 6.6946x - 35.624
R² = 0.6423
Beaver harvest
Year

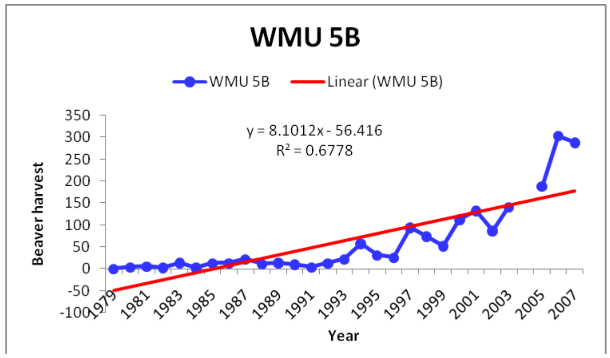

WMU 4C
WMU 4C
Linear (WMU 4C)
y = 6.1447x + 3.1342
R² = 0.3225
Beaver harvest
Year

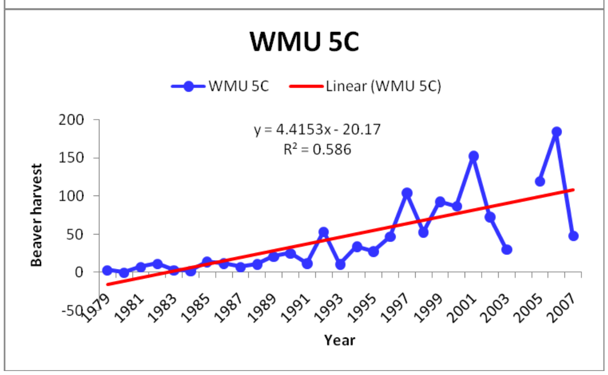

WMU 4D
WMU 4D
Linear (WMU 4D)
y = 8.7269x + 18.574
R² = 0.5388
Beaver harvest
Year

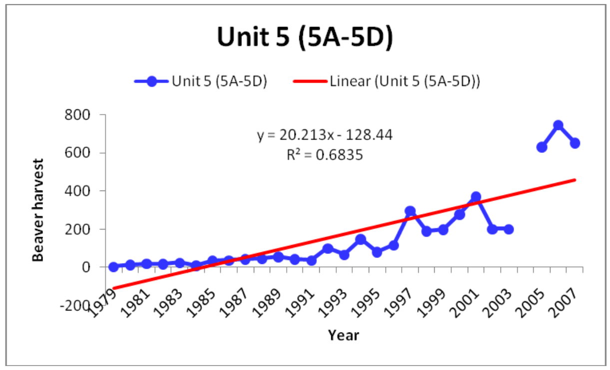

WMU 4E
WMU 4E
Linear (WMU 4E)
y = 8.6185x + 5.0614
R² = 0.6428
Beaver harvest
Year


Unit 4 (WMUs 4A-4E)
Unit 4 (WMUs 4A-4E)
Linear (Unit 4 (WMUs 4A-4E))
y = 36.025x + 16.599
R² = 0.5748
Beaver harvest
Year









Note: WMU 5D was recently created and harvest data prior to 2005 were not estimated for this unit. Trend analysis was omitted for this WMU.

APPENDIX 5. Beaver population and harvest monitoring methods used by northeastern jurisdictions in North America during 2008.

Jurisdiction	Population monitoring			Harvest determination methods
	Methods	Biological data sources	Biological data types collected	
Connecticut				Pelt tagging
Delaware	Hunter survey			Mail survey
Maine				Pelt tagging
Maryland	Hunter survey			Furbuyer records
Massachusetts	Plot/Transect surveys Sighting reports	Under emergency permit		Mail survey Pelt tagging
New Brunswick		Incidental take		Furbuyer records
New Hampshire	Hunter survey			Furbuyer records Trapper reports
New Jersey	Roadkills Sighting reports Field inventory		Age Sex	Pelt tagging
New York	Plot/Transect surveys			Mail survey Pelt tagging
Newfoundland		Harvest carcasses		Pelt tagging Furbuyer records Trapper reports
Nova Scotia	Hunter survey Plot/Transect surveys	Harvest carcasses	Age Sex Reproductive status	Furbuyer records Trapper reports
Ontario	Sighting reports			Furbuyer records Trapper reports
Pennsylvania				Mail survey
Prince Edward Island	Plot/Transect surveys	Harvest carcasses	Age Sex Reproductive status Body condition	Phone survey Other method
Quebec				Furbuyer records
Rhode Island	Colony surveys			Pelt tagging Trapper reports
Vermont	Plot/Transect surveys			Mail survey Furbuyer records
Virginia				Furbuyer records
West Virginia	Sighting reports Bridge surveys	Harvest carcasses	Sex	Pelt tagging Furbuyer records

APPENDIX 6. Objective and supporting strategy completion timetable and agency organizational divisions required for implementation.

Objective	Strategy	Year of completion 2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Responsible agency organizational division[1]
1.1 Annually monitor beaver status and population trends.	**1.1.1** Determine population status from annual Wildlife Conservation Officer furbearer surveys.	●	●	●	●	●	●	●	●	●	●	Regions BWM
	1.1.2 Estimate population size within each Wildlife Management Unit (WMU) or other defined unit from annual beaver colony surveys.		●	●	●	●	●	●	●	●	●	Regions BWM
1.2 Assure accuracy of population monitoring methods by 2012.	**1.2.1** Train survey personnel to accurately recognize and record beaver activity, sign, and structures.		●	●								Regions BWM
	1.2.2 Develop and test a field technique to estimate family group size based on characteristics of constructed features (age, number, and height of dams, condition of lodge/den, food cache size).		●	●								BWM
1.3 Develop a model to monitor population changes within each WMU or other defined unit by 2013.	**1.3.1** Estimate age- or age class-specific fecundity.		●	●	●							Regions BWM
	1.3.2 Estimate age- or age class-specific mortality from the harvest and other causes.		●	●	●							Regions BWM
	1.3.3 Determine how beaver regulations such as bag limit, season length, trap distance from beaver structure, and number and type of trapping devices permitted influence the harvest.		●	●	●							BWM

[1]*Regions* – regional office and field staff; *BWM* – Bureau of Wildlife Management; *BHM* – Bureau of Wildlife Habitat Management; *BI&E* – Bureau of Information and Education; *BATS* – Bureau of Automated Technology Services.

Objective	Strategy	Year of completion										Responsible agency organizational division[1]
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
1.4 Develop a geographic information system-based beaver habitat suitability model by 2012.	**1.4.1** Identify and map suitable habitat features necessary for beaver occupancy.		●	●								Regions BWM BHM BATS
	1.4.2 Map unoccupied, but potential beaver habitat.		●	●								Regions BWM BHM BATS
1.5 Evaluate the practice of beaver trap and transfer for establishing colonies in new locations by 2016.	**1.5.1** Determine movement patterns and survival of relocated beavers.				●	●	●	●				BWM
	1.5.2 Evaluate the cost of trapping and transferring beavers.				●	●	●	●				Regions BWM
	1.5.3 Evaluate habitat characteristics of relocation sites, season of year at time of release, and age of released trap-and-transfer beavers that resulted in successful and unsuccessful population establishment.				●	●	●	●				BWM
1.6 Manage beaver populations on public lands for maximum wildlife benefit.	**1.6.1** Integrate beaver habitat needs into the state game lands planning process to benefit beaver colony establishment and long term food supply.		●	●	●	●	●	●	●	●	●	Regions BWM BHM
	1.6.2 Trap and transfer nuisance beavers to suitable habitat to establish new colonies if ecologically and fiscally feasible..				●	●	●	●	●	●	●	Regions BWM BHM
	1.6.3 Establish protected beaver colonies on selected state game lands to create population refuges from which range expansion can occur.				●	●						Regions BWM BHM

[1]*Regions* – regional office and field staff; *BWM* – Bureau of Wildlife Management; *BHM* – Bureau of Wildlife Habitat Management; *BI&E* – Bureau of Information and Education; *BATS* – Bureau of Automated Technology Services.

Objective	Strategy	Year of completion										Responsible agency organizational division[1]
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
2.1 Refine current beaver harvest estimates from furtaker mail surveys to monitor harvest trends by 2012.	**2.1.1** Establish a means of refining mail survey harvest estimates based on comparisons of actual harvests determined from mandatory tagging with harvest estimates from furtaker mail surveys during the same years.	●	●	●								BWM BATS
2.2 Explore methods of obtaining more precise harvest estimates in areas requiring more accurate harvest monitoring by 2013.	**2.2.1** Examine options available for mandatory beaver harvest reporting or checking.		●	●								BWM BATS
2.3 Develop additional measures of harvest trends by 2013.	**2.3.1** Determine measures of catch per unit effort by adding trapping effort questions to the annual furtaker survey or point of sale surveys.		●	●	●	●	●	●	●	●	●	BWM BATS
2.4 Develop more understandable beaver regulations by 2012.	**2.4.1** Review beaver season limit, trapping regulation descriptions, and beaver structure definitions in the Hunting and Trapping Digest to improve trapper understanding of these terms.		●	●								BWM BWP BI&E
	2.4.2 Define beaver structures such as lodge, bank den, dam, and feed bed and incorporate them into state regulations.		●	●								BWM BWP BI&E

[1]*Regions* – regional office and field staff; *BWM* – Bureau of Wildlife Management; *BHM* – Bureau of Wildlife Habitat Management; *BI&E* – Bureau of Information and Education; *BATS* – Bureau of Automated Technology Services.

Objective	Strategy	Year of completion										Responsible agency organizational division[1]
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
3.1 Evaluate the frequency and extent of beaver damage complaints annually.	**3.1.1** Annually survey WCOs to obtain the number of beaver damage complaints received and information on type of damage.		●	●	●	●	●	●	●	●	●	Regions BWM
3.2 Assess the need for public outreach dealing with beaver damage by 2013.	**3.2.1** Conduct a survey to determine the public's knowledge of beavers, benefits of beaver habitat, and options for control as well as the public's desired beaver population level.		●	●	●							BWM
4.1 Develop guidelines for managing beaver family groups on private land to maximize wildlife use and wetland longevity by 2013.	**4.1.1** Prepare a Game News article or brochure describing the benefits of a beaver colony and how to manage it for maximum wildlife use.			●	●							BWM BI&E
	4.1.2 Develop a web page focusing on beaver life history and habitat benefits.			●	●							BWM BI&E
4.2 Promote the environmental benefits of beavers by 2014.	**4.2.1** Incorporate information about beaver ecology and how beaver habitat benefits other wildlife into agency educational materials.				●	●						BWM BI&E

[1]*Regions* – regional office and field staff; *BWM* – Bureau of Wildlife Management; *BHM* – Bureau of Wildlife Habitat Management; *BI&E* – Bureau of Information and Education; *BATS* – Bureau of Automated Technology Services.

Objective	Strategy	Year of completion										Responsible agency organizational division[1]
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
5.1 Annually allow a trapping season for beavers.	**5.1.1** Establish an annual trapping season for beavers to include the period of maximum pelt primeness.	●	●	●	●	●	●	●	●	●	●	BWM
	5.1.2 Investigate the possibility of establishing a youth-mentored trapping program to include beaver taking.		●	●								BWM BI&E
5.2 Develop wildlife viewing opportunities in beaver wetlands..	**5.2.1** Establish interpretive wildlife viewing areas on state game lands that highlight the contributions of beaver engineering.				●	●	●	●	●	●	●	Regions BWM BI&E

[1]*Regions* – regional office and field staff; *BWM* – Bureau of Wildlife Management; *BHM* – Bureau of Wildlife Habitat Management; *BI&E* – Bureau of Information and Education; *BATS* – Bureau of Automated Technology Services.

APPENDIX 7. Summary of public comments.