An annotated bibliography of beaver literature

Prepared for the
Oregon Department of Fish and Wildlife's Beaver Working Group
by Dana Sanchez, Department of Fisheries and Wildlife, Oregon State University

Subjects

Climate change
Conservation of other wildlife species
Damage
Dams (including construction, location, and as index to population size/density)
Disease, including toxicology
Dispersal, movements, and home range
Ecosystem function
Floodplain functions (and ecological relationships)
Food habits and diet
Genetics
Habitat Relationships
Human dimensions
Hydrology
Interspecific interactions and relationships
Management
Monitoring and survey methods
Population dynamics and demographics
Relationships with invasive species
Relationships with Salmonid species
Relocation (translocation)
Reproduction
Restoration
Trapping effects
Urban and road crossing impacts
Wetland function and restoration

Climate change

Boudreau, R. E. A., J. M. Galloway, R. T. Patterson, A. Kumar and F. A. Michel. 2005.
A paleolimnological record of Holocene climate and environmental change in the Temagami region, northeastern Ontario.
Journal of Paleolimnology. 33:445-461.
The Arcellacean (Thecamoebian) fauna was assessed in five Holocene sediment cores obtained from James and Granite lakes in the Temagami region of northeastern Ontario. In addition, palynological analysis was carried out on two of these cores, one each from James and Granite lakes. The first indication of postglacial colonization by plants was the appearance of rare Cupressaceae pollen, dated to 10,800 yr BP. Plant diversity began to increase by 10,770 yr BP when Pinus spp. and Larix migrated into the area. The first appearance of arcellaceans occurred after 9650 yr BP in assemblages dominated by Centropyxis constricta and opportunistic

Centropyxis aculeata. High abundances of charophytes in the cores until 8800 yr BP indicated that macroalgae were proliferating at this time. This deposition is interpreted to have occurred during the draining of an ice-marginal lake following the retreat of the Laurentide Ice Sheet. Based on pollen analysis, warmer conditions associated with the Holocene Hypsithermal prevailed in the area from 6250 to 4115 yr BP. The stable, open Great Lakes - St. Lawrence type forest that developed here at the beginning of the Hypsithermal continues to prevail to the present. The periodic colonization of the lake by beavers (Castor canadensis) acted as a control on water- level and eutrophication through the Holocene. Evidence of eutrophication was indicated in the core samples by the abundance of high levels of the alga Pediastrum and the arcellacean Cucurbitella tricuspis. Eutrophication periodically developed when beavers dammed a site, causing the rate of flow in drainage streams to slow and stagnant conditions occurred. When the site became depleted of the nearby trees, which were preferred by beaver (Betula, Alnus and Populus), the dam would be abandoned, causing the water- level to drop. Stagnant conditions were reduced as flow levels increased, reducing eutrophication and resulting in recovering forest stands. In addition, the lowering water levels would result in encroachment of the forest along the lake shore. This cycle occurred many times in the history of this lake as indicated by fluctuations in the size of arcellacean populations.

Hood, G. A. and S. E. Bayley. 2008.
Beaver (Castor canadensis) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada.
Biological Conservation. 141:556-567.
Shallow open water wetlands provide critical habitat for numerous species, yet they have become increasingly vulnerable to drought and warming temperatures and are often reduced in size and depth or disappear during drought. We examined how temperature, precipitation and beaver (Castor canadensis) activity influenced the area of open water in wetlands over a 54-year period in the mixed-wood boreal region of east-central Alberta, Canada. This entire glacial landscape with intermittently connected drainage patterns and shallow wetland lakes with few streams lost all beaver in the 19th century, with beaver returning to the study area in 1954. We assessed the area of open water in wetlands using 12 aerial photo mosaics from 1948 to 2002, which covered wet and dry periods, when beaver were absent on the landscape to a time when they had become well established. The number of active beaver lodges explained over 80% of the variability in the area of open water during that period. Temperature, precipitation and climatic variables were much less important than beaver in maintaining open water areas. in addition, during wet and dry years, the presence of beaver was associated with a 9-fold increase in open water area when compared to a period when beaver were absent from those same sites. Thus, beaver have a dramatic influence on the creation and maintenance of wetlands even during extreme drought. Given the important role of beaver in wetland preservation and in light of a drying climate in this region, their removal should be considered a wetland disturbance that should be avoided. (C) 2007 Elsevier Ltd. All rights reserved.

Norment, C. J., A. Hall and P. Hendricks. 1999.
Important bird and mammal records in the Thelon River Valley, Northwest Territories: range expansions and possible causes.
Canadian Field-Naturalist. 113:375-385 | 375.

Included in information on the status of 50 bird and five mammal species in the Thelon River Valley, Northwest Territories, Canada are nine northward and three southward breeding range extensions for birds, along with 16 species not previously recorded in the Thelon Wildlife Sanctuary. Several hypotheses may explain northward range expansions, including a recent warming trend at the northern treeline during the 1970s and 1980s.

Robinson, S., A. B. Beaudoin, D. G. Froese, J. Doubt and J. J. Clague. 2007.
Plant macrofossils associated with an early Holocene beaver dam in interior Alaska.
Arctic. 60:430-438.
Dynamic climate changes and expansion of new biomes characterize the late Pleistocene-early Holocene of eastern Beringia. Analysis of plant macrofossils from an early Holocene (ca. 9300 14C yrs BP) beaver dam in central Alaska provides insight into the local environment and vegetation. The plant macrofossil assemblage comprises remains of trees and shrubs, graminoids, and forbs, including Betula sp., Carex sp., Rubus sp., Eleocharis sp., Scirpus sp., Potamogeton sp., Najas flexilis and Typha latifolia, indicative of standing water of a beaver pond. Bryophytes from the beaver dam include Warnstorfia spp. and Drepanocladus aduncus, suggesting shallow, stagnant, or slow-moving water. The presence of Najas flexilis, Typha latifolia, and modern beaver (Castor canadensis) suggest that central Alaska had a warmer climate during the early Holocene.

Skelly, D. K. and L. K. Freidenburg. 2000.
Effects of beaver on the thermal biology of an amphibian.
Ecology Letters. 3:483-486.
It is often assumed that ecological interactions happen at rapid rates relative to evolutionary change. In this study the authors examined the development and physiology of an amphibian (Rana sylvatica) from populations found in forested wetlands, and from wetlands that had been cleared by reinvading beaver (Castor canadensis). Embryos from beaver wetlands hatched at lower rates when raised in a shaded, common garden setting compared with embryos from forested wetlands. Larvae from beaver wetlands had higher critical thermal maxima compared with conspecifics from forested wetlands. These patterns suggest that R. sylvatica populations may have diverged rapidly (in less than 36 years) in response to changes in their environment induced by another species. Other agents of thermal change, such as anthropogenic landscape conversion or alteration of global climate, could have analogous impacts on wetland dependent species such as amphibians.

Telfer, E. S. 2004.
Continuing environmental change - An example from Nova Scotia.
Canadian Field-Naturalist. 118:39-44.
Information from personal experience, from community elders and published literature served as a basis for evaluating environmental changes in the District of North Queens and adjacent areas of Southwestern Nova Scotia over the past century. Major events included disappearance of the Caribou (Rangifer tarandus), the arrival of White-tailed Deer (Odocoileus virginianus), the severe reduction of Canada Yew (Taxus canadensis), disappearance of Lynx (Lynx canadensis), a major dieoff of Striped Skunks (Mephitis mephitis), decline of American Beech (Fagus grandifolia), the loss of mature birch (Betula spp.), the severe reduction of Moose (Alces alces), the arrival of the American Dog Tick (Dermacentor variabilis) and Coyotes (Canis latrans), and

the restoration of Beaver (Castor canadensis). The proximate cause of many of those changes were plant and animal disease, while the ultimate causes were naturally occurring animal range expansion and human impacts. The warming of the climate over the past 150 years probably played a role. The nature and timing of the events could not have been predicted.

Wolf, E. C., D. J. Cooper and N. T. Hobbs. 2007.
Hydrologic regime and herbivory stabilize an alternative state in Yellowstone National Park.
Ecological Applications. 17:1572-1587 | 1572-87.
The article focuses in determining the relative influence of hydrologic regimes, as controlled by climate variation, beaver damming, and landscape changes, on the process of Yellowstone's northern range. The study was made with four streams on the northern range of Yellowstone National Park, USA. The four streams were selected because they have relatively large willow populations, have a riparian zone where groundwater is supported by streamflows, and lack significant hillslope groundwater inflows. Willow establishment data were compared to 20th century streamflow and precipitation data in detecting climatic influences on the timing of establishment. The reduced frequency of willow establishment during the 20th century is likely both a direct and indirect effect of elk browsing.

Conservation of other wildlife species

Allred, M. 1980.
A re-emphasis on the value of the beaver in natural resource conservation.
Idaho Academy of Science. 16:3-10.

Askins, R. A., F. Ch vez-Ram¡rez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf and P. D. Vickery. 2007.
Conservation of grassland birds in North America: understanding ecological processes in different regions: report of the AOU committee on conservation.
Ornithological Monographs. 64:1-46.
[unedited] Many species of birds that depend on grassland or savanna habitats have shown substantial overall population declines in North America. To understand the causes of these declines, we examined the habitat requirements of birds in six types of grassland in different regions of the continent. Open habitats were originally maintained by ecological drivers (continual and pervasive ecological processes) such as drought, grazing, and fire in tallgrass prairie, mixed-grass prairie, shortgrass prairie, desert grassland, and longleaf pine savanna. By contrast, grasslands were created by occasional disturbances (e.g., fires or beaver [Castor canadensis] activity) in much of northeastern North America. The relative importance of particular drivers or disturbances differed among regions. Keystone mammal species-grazers such as prairie-dogs (Cynomys spp.) and bison (Bison bison) in western prairies, and dam-building beavers in eastern deciduous forests-played a crucial, and frequently unappreciated, role in maintaining many grassland systems. Although fire was important in preventing invasion of woody plants in the tallgrass and moist mixed prairies, grazing played a more important role in maintaining the typical grassland vegetation of shortgrass prairies and desert grasslands. Heavy grazing by prairie- dogs or bison created a low "grazing lawn" that is the preferred habitat for many grassland bird species that are restricted to the shortgrass prairie and desert grasslands. Ultimately, many species of grassland birds are vulnerable because people destroyed their

breeding, migratory, and wintering habitat, either directly by converting it to farmland and building lots, or indirectly by modifying grazing patterns, suppressing fires, or interfering with other ecological processes that originally sustained open grassland. Understanding the ecological processes that originally maintained grassland systems is critically important for efforts to improve, restore, or create habitat for grassland birds and other grassland organisms. Consequently, preservation of large areas of natural or seminatural grassland, where these processes can be studied and core populations of grassland birds can flourish, should be a high priority. However, some grassland birds now primarily depend on artificial habitats that are managed to maximize production of livestock, timber, or other products. With a sound understanding of the habitat requirements of grassland birds and the processes that originally shaped their habitats, it should be possible to manage populations sustainably on "working land" such as cattle ranches, farms, and pine plantations. Proper management of private land will be critical for preserving adequate breeding, migratory, and winter habitat for grassland and savanna species.

Askins, R. A., F. Ch vez-Ram¡rez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf and P. D. Vickery. 2007.
Conservation of grassland birds in North America: Understanding ecological processes in different regions.
The Auk: a quarterly journal of ornithology. 124:1-46.
Many species of birds that depend on grassland or savanna habitats have shown substantial overall population declines in North America. To understand the causes of these declines, we examined the habitat requirements of birds in six types of grassland in different regions of the continent. Open habitats were originally maintained by ecological drivers (continual and pervasive ecological processes) such as drought, grazing, and fire in tallgrass prairie, mixed-grass prairie, shortgrass prairie, desert grassland, and longleaf pine savanna. By contrast, grasslands were created by occasional disturbances (e.g., fires or beaver [Castor canadensis] activity) in much of northeastern North America. The relative importance of particular drivers or disturbances differed among regions. Keystone mammal species-grazers such as prairie-dogs (Cynomys spp.) and bison (Bison bison) in western prairies, and dam-building beavers in eastern deciduous forests-played a crucial, and frequently unappreciated, role in maintaining many grassland systems. Although fire was important in preventing invasion of woody plants in the tallgrass and moist mixed prairies, grazing played a more important role in maintaining the typical grassland vegetation of shortgrass prairies and desert grasslands. Heavy grazing by prairie-dogs or bison created a low "grazing lawn" that is the preferred habitat for many grassland bird species that are restricted to the shortgrass prairie and desert grasslands. Ultimately, many species of grassland birds are vulnerable because people destroyed their breeding, migratory, and wintering habitat, either directly by converting it to farmland and building lots, or indirectly by modifying grazing patterns, suppressing fires, or interfering with other ecological processes that originally sustained open grassland. Understanding the ecological processes that originally maintained grassland systems is critically important for efforts to improve, restore, or create habitat for grassland birds and other grassland organisms. Consequently, preservation of large areas of natural or seminatural grassland, where these processes can be studied and core populations of grassland birds can flourish, should be a high priority. However, some grassland birds now primarily depend on artificial habitats that are managed to maximize production of livestock, timber, or other products. With a sound

understanding of the habitat requirements of grassland birds and the processes that originally shaped their habitats, it should be possible to manage populations sustainably on "working land" such as cattle ranches, farms, and pine plantations. Proper management of private land will be critical for preserving adequate breeding, migratory, and winter habitat for grassland and savanna species. (Author)

Baker, B. W., H. C. Ducharme, D. C. S. Mitchell, T. R. Stanley and H. R. Peinetti. 2005.
Interaction of beaver and elk herbivory reduces standing crop of willow.
Ecological Applications. 15:110-118.
Populations of beaver and willow have not thrived in riparian environments that are heavily browsed by livestock or ungulates, such as elk. The interaction of beaver and elk herbivory may be an important mechanism underlying beaver and willow declines in this competitive environment. We conducted a field experiment that compared the standing crop of willow three years after simulated beaver cutting on paired plants with and without intense elk browsing ([approximately]85% utilization rate). Simulated beaver cutting with intense elk browsing produced willow that was small (biomass and diameter) and short, with far fewer, but longer, shoots and a higher percentage of dead biomass. In contrast, simulated beaver cutting without elk browsing produced willow that was large, tall, and leafy, with many more, but shorter, shoots (highly branched) and a lower percentage of dead biomass. Total stem biomass after three years was 10 times greater on unbrowsed plants than on browsed plants. Unbrowsed plants recovered 84% of their pre-cut biomass after only two growing seasons, whereas browsed plants recovered only 6%. Thus, the interaction of beaver cutting and elk browsing strongly suppressed the standing crop of willow. We predict that a lack of willow suitable as winter food for beaver can cause beaver populations to decline, creating a feedback mechanism that reduces beaver and willow populations. Thus, intense herbivory by ungulates or livestock can disrupt beaver-willow mutualisms that naturally occur in less competitive environments.

Berner, L. M. 1952.
Big game management on state parks.
South Dakota Conservation Digest. 19:11-13.
A long and thoughtful paper based in part on a nationwide questionnaire about practice and principle, and in part on knowledge of the effects of herbivore overpopulations. The state park objective is to keep the fauna and flora as nearly in its original condition as possible. This aim is frequently defeated by tolerance of deer, beaver, and other herbivore populations that are large enough to injure the vegetation. Resulting conditions are far from natural, and eventually the animals themselves may suffer from overpopulation. Controls should be planned before they are needed and range conditions should be constantly checked. Park men and game men should cooperate in this. Controls, preferably controlled public hunting, should be instituted before any native plant is eliminated and certainly before the situation becomes acute. Native plants and animals may well be reintroduced, and clearings may be made to simulate the effects of fire and insect damage, but exotic plants and animals should not be introduced.

Dalbeck, L., B. Luescher, D. Ohlhoff and B. L□scher. 2007.
Beaver ponds as habitat of amphibian communities in a central European highland.
Amphibia Reptilia. 28:493-501.

The Eurasian beaver Castor fiber, formerly occurred across the Palaearctic, but was nearly eradicated in the 19th century. Due to reintroductions in the 20th century, beaver populations are increasing and now extend into highland areas. Natural still waters are scarce in highlands of Central Europe. Therefore the question arises, "Are beaver ponds essential habitats for amphibians?", especially since fishes, predators of amphibian larval stages, also inhabit beaver ponds. We investigated the amphibian fauna of one typical valley in the Eifel, that was colonized by beavers in 1981, and compared areas with and without beaver ponds. All anuran species of the region occupied beaver ponds, including species that were absent (Alytes obstetricans, Bufo bufo and Rana kl. esculenta) or rare (Rana temporaria) in natural waters. Alytes obstetricans obviously benefited from pond construction and the removal of trees by beavers which leads to sunny plots along the slopes of the valley, crucial habitat for this species. The urodelans Salamandra salamandra, Triturus alpestris and Triturus helveticus were widely distributed in beaver ponds. Our results show clearly, that beaver altered landscapes offer high quality habitats for amphibians in our study area. Due to a considerable increase of habitat heterogeneity in impounded streams, the predator Salmo trutta was not able to extirpate the amphibian fauna. We conclude that the historic effects of beavers need to be considered for a proper understanding of patterns of amphibian distribution and habitat requirements in Central European Highlands. Furthermore, beaver-created landscapes will be of future relevance for conservation of endangered species, like Alytes obstetricans.

Danell, K., T. Willebrand and L. Baskin. 1998.
Mammalian herbivores in the boreal forests: their numerical fluctuations and use by man. Conservation Ecology. 2:1-20.
The authors present an account of the population fluctuations of mammalian herbivores occurring in the boreal forests of the Nearctic and Palaearctic and their interrelation with humans. The boreal forests support rich natural resources that have been used over centuries by mankind for survival. The mammalian species are the most important resource that have provided man with food and products of commercial importance like antlers and hides. Their impact on plant succession, and their role in increasing the wetland mosaic and altering the hydrology of important ecosystems is also significant. These mammalian herbivores exhibit fluctuating cycles that are evident on different trophic levels. There are three types of fluctuations. The first two groups contain species with regular fluctuations and the third group contains species with irregular fluctuations. Thus, a variation in population size that lacks stable resource-dependent equilibrium seems to be characteristic of population fluctuations of many large ungulates. This study indicated that forest management that reduces the structural and spatial diversity at the stand, as well as at the landscape, level affects boreal forest habitats. Management of silvicultural that supports same age trees improves conditions for species favoring young forest stands, but it makes the situation worse for species that depend on old-growth forests. Another aim of management is the attempt at successful increase of population sizes of mammals. However, this population increase might go out of control leading to destabilization and destruction. Therefore it can be concluded that management of boreal forest ecosystems should be both substantial and long lasting.

Degraaf, R. M. and M. Yamasaki. 2003.
Options for managing early-successional forest and shrubland bird habitats in the northeastern United States.

Forest Ecology and Management. 185:179-191.
Historically, forests in the northeastern United States were disturbed by fire, wind, Native American agriculture, flooding, and beavers (Castor canadensis). Of these, wind and beavers are now the only sources of natural disturbance. Most disturbance-dependent species, especially birds, are declining throughout the region whereas species affiliated with mature forests are generally increasing or maintaining populations. Disturbance must be simulated for conservation of early-successional species, many of which are habitat specialists compared to those associated with mature forests. Both the maintenance of old fields and forest regeneration are needed to conserve brushland species. Regenerating forest habitats are more ephemeral than other woody early-successional habitats. The types and amounts of early-successional habitats created depend on the silvicultural system used, patch size selected, time between regeneration cuts, and rotation age. We recommend that group selection and patch cuts should be at least 0.8 ha, and patches should be generated approximately every 10-15 years depending on site quality. Regeneration of intolerant and mid-tolerant tree species should be increased or maintained in managed stands. Also, frost pockets, unstocked, or poorly-stocked stands can provide opportunities to increase the proportion of early-successional habitats in managed forests.

Dollar, T. 2002.
Leave it to beavers.
Wildlife Conservation. 105:28-35 | 28.
The author describes the role beavers play in maintaining the wetland ecosystem at San Pedro Riparian National Conservation Area in Arizona. Human activities like mining, grazing, and woodcutting in the late 19th century and urbanization and water pumping recently, led to severe degradation of this ecosystem. The San Pedro River over the years was severely diminished by human activities and the beavers that were a natural part of the ecosystem were wiped out by poaching. In 1988, in a series of land exchanges the 58,000 acre San Pedro Riparian National Conservation Area, encompassing a 40 mile stretch of the river, was established under the management of the U.S. Bureau of Land Management (BLM). Since March 1999, 10 beavers were trapped from several areas, fitted with radio-transmitters, and reintroduced to the San Pedro NCA where they immediately formed pairs and started their damming activities. Biologists hope that in the coming years around 20 beaver colonies will develop along the river. Wildlife biologist Mark Fredlake, who monitors the activities of the reintroduced beavers, observed that after a wildfire and devastating floods that damaged four of the five beaver dens, the beavers survived and got back to building dams. Beaver dams help restore the ecosystem and the largest of the dams, 75 feet wide and around 3 m high, had backed water for a quarter-mile upstream. Areas that had dried up over the years started to re-grow wetland vegetation. With protection, the habitat has improved and around 220 species of birds are reported to breed here and over 450 bird, 47 amphibian and reptile, and 100 butterfly species have been observed. However, urban sprawl and unchecked water pumping is draining the river and all efforts of the beavers will come to naught unless these activities are checked.

Foster, D. R., G. Motzkin, D. Bernardos and J. Cardoza. 2002.
Wildlife dynamics in the changing New England landscape.
Journal of Biogeography. 29:1337-1357.
Aim: Over the past four centuries the eastern US has undergone remarkable landscape and land-use transformations involving deforestation, intensive agriculture, farm abandonment,

reforestation and human population increase that have induced sweeping changes in wildlife assemblages, abundances, and distributions. This study compiles data on major wildlife species and seeks to identify broad population trends and to address both fundamental and applied questions regarding these long-term patterns. Location: The study encompasses the state of Massachusetts, which is broadly representative of the habitat conditions and landscape and cultural history of other New England states. Methods: A wide range of historical sources of data were used including town histories, newspaper and other popular accounts, scientific studies, museum collections, compiled trapping, bounty and harvest records, explorer accounts, and agency records. Statewide distribution maps and generalized population trends were assembled for individual species where practical, and major trends in species trajectories were identified. Emphasis was placed on mammals and birds for which data are readily available. Results: Although species exhibited highly individualistic long-term dynamics in response to habitat change and human pressure, six major trajectories of species changes are identified: (1) large mammals and birds that declined historically and increased recently, (2) open-land species that went from low to high abundance with the creation of open habitat but are in rapid decline today in the heavily wooded landscape, (3) species regionally extirpated or globally extinct, (4) species expanding their range from the west, north and south, (5) non-native, introduced species, and (6) persistent species not exhibiting major long-term trends. Currently, wildlife populations are changing at a remarkable rate leading to significant ecological impacts on the landscape and many other species, creating major conservation and management challenges, and generating novel and oftentimes significant conflicts with human values. Conclusions: The rate of historical and current changes in wildlife assemblages pose many scientific and conservation challenges, especially in this heavily forested but highly populated landscape. Historical data are fragmentary and oftentimes uncertain, modern information on wildlife populations is similarly incomplete, and small populations of species that are immigrating, expanding or declining from previously high levels pose major sampling problems; development of conservation and management plans for rapidly expanding populations of large woodland mammals (e.g. moose, coyote, deer, bears, beaver) and for declining populations of cherished species that are dependent on cultural landscapes generates conflicting directives; and educating, and modifying the behaviour of a human population that is living in but separated from nature is a difficult enterprise. The future is guaranteed to bring major dynamics in these historically novel species assemblages.

Hebblewhite, M., C. A. White, C. G. Nietvelt, J. A. McKenzie, T. E. Hurd, J. M. Fryxell, S. E. Bayley and P. C. Paquet. 2005.
Human activity mediates a trophic cascade caused by wolves.
Ecology. 86:2135-2144.
Experimental evidence of trophic cascades initiated by large vertebrate predators is rare in terrestrial ecosystems. A serendipitous natural experiment provided an opportunity to test the trophic cascade hypothesis for wolves (Canis lupus) in Banff National Park, Canada. The first wolf pack recolonized the Bow Valley of Banff National Park in 1986. High human activity partially excluded wolves from one area of the Bow Valley (low-wolf area), whereas wolves made full use of an adjacent area (high-wolf area). We investigated the effects of differential wolf predation between these two areas on elk (Cervus elaphus) population density, adult female survival, and calf recruitment; aspen (Populus tremuloides) recruitment and browse intensity; willow (Salix spp.) production, browsing intensity, and net growth; beaver (Castor canadensis)

density; and riparian songbird diversity, evenness, and abundance. We compared effects of recolonizing wolves on these response variables using the log response ratio between the low-wolf and high-wolf treatments. Elk population density diverged over time in the two treatments, such that elk were an order of magnitude more numerous in the low-wolf area compared to the high-wolf area at the end of the study. Annual survival of adult female elk was 62% in the high-wolf area vs. 89% in the low-wolf area. Annual recruitment of calves was 15% in the high-wolf area vs. 27% without wolves. Wolf exclusion decreased aspen recruitment, willow production, and increased willow and aspen browsing intensity. Beaver lodge density was negatively correlated to elk density, and elk herbivory had an indirect negative effect on riparian songbird diversity and abundance. These alternating patterns across trophic levels support the wolf-caused trophic cascade hypothesis. Human activity strongly mediated these cascade effects, through a depressing effect on habitat use by wolves. Thus, conservation strategies based on the trophic importance of large carnivores have increased support in terrestrial ecosystems.

Hood, G. A. and S. E. Bayley. 2008.
Beaver (Castor canadensis) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada.
Biological Conservation. 141:556-567.
Shallow open water wetlands provide critical habitat for numerous species, yet they have become increasingly vulnerable to drought and warming temperatures and are often reduced in size and depth or disappear during drought. We examined how temperature, precipitation and beaver (Castor canadensis) activity influenced the area of open water in wetlands over a 54-year period in the mixed-wood boreal region of east-central Alberta, Canada. This entire glacial landscape with intermittently connected drainage patterns and shallow wetland lakes with few streams lost all beaver in the 19th century, with beaver returning to the study area in 1954. We assessed the area of open water in wetlands using 12 aerial photo mosaics from 1948 to 2002, which covered wet and dry periods, when beaver were absent on the landscape to a time when they had become well established. The number of active beaver lodges explained over 80% of the variability in the area of open water during that period. Temperature, precipitation and climatic variables were much less important than beaver in maintaining open water areas. in addition, during wet and dry years, the presence of beaver was associated with a 9-fold increase in open water area when compared to a period when beaver were absent from those same sites. Thus, beaver have a dramatic influence on the creation and maintenance of wetlands even during extreme drought. Given the important role of beaver in wetland preservation and in light of a drying climate in this region, their removal should be considered a wetland disturbance that should be avoided.

Lesica, P. and S. Miles. 2004.
Beavers indirectly enhance the growth of Russian olive and tamarisk along eastern Montana rivers.
Western North American Naturalist. 64:93-100.
Russian olive and tamarisk are introduced woody plants invading western North American riparian communities. Beavers can play an important role in structuring these communities by removing the dominant cottonwood trees. Our study explored the way in which beavers interact with cottonwood, Russian olive, and tamarisk along 4 rivers on the Great Plains of eastern Montana. We sampled cottonwood stands that supported populations of 1 or both exotic species,

recording beaver damage and density in addition to size and age of cottonwood, Russian olive, and tamarisk. In stands where beaver had been present, they felled an average of 80% of cottonwood trees while rarely using Russian olive or tamarisk. Beaver foraging was apparent in nearly 90% of stands within 50 m of the river channel but only 21% of stands farther away, creating a sunny corridor along the river channel that may increase the invasive potential of Russian olive and tamarisk. Growth rates of both Russian olive and tamarisk were substantially higher where beavers had reduced the cottonwood canopy cover. Managers wishing to reintroduce beavers should consider the potential effect on invasive exotic plants.

Martell, K. A., A. L. Foote and S. G. Cumming. 2006.
Riparian disturbance due to beavers (Castor canadensis) in Alberta's boreal mixedwood forests: implications for forest management.
Ecoscience. 13:164-171.
Alberta's boreal mixedwood forest has seen intensifying industrial activity in the past several decades, largely from logging and petroleum extraction. At the same time, populations of North American beaver (Castor canadensis) have been recovering from past near-extirpation. We conducted detailed field surveys of six beaver dam sites on low-order streams in northeastern Alberta and examined a 50-y chronosequence of air photos at each site to quantify beavers' effects on riparian forests. Beaver activity increased the width and diversity of riparian zones along first- and second-order streams. Over the 50-y time sequence, dam number increased considerably and beaver activity converted narrow, entirely lotic habitats to a mix of lentic and lotic. Current forestry operating ground rules in Alberta require 30- to 60-m unharvested buffer strips on permanent streams. Around dams, beaver felling removed most or all Populus trees within 30-40 m of the pond edge. The abundance of dams and their tendency to be built in chains altered vegetation structure over long stretches of riparian corridors. Beavers thus could be removing forest cover from entire buffer strips in direct conflict with forest management objectives. We argue that beavers may be the primary disturbance agent structuring riparian zones on low-order streams in the study area and that unharvested riparian buffer strips should be much wider than currently prescribed in order both to provide beaver habitat and to ensure appropriate protection of riparian habitats.

Pollock, M. M., G. R. Pess and T. J. Beechie. 2004.
The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA.
North American Journal of Fisheries Management. 24:749-760.
The use of beaver Castor canadensis ponds by juvenile coho salmon Oncorhynchus kisutch and other fishes has been well established. However, the population-level effects on coho salmon resulting from the widespread removal of millions of beaver and their dams from Pacific Coast watersheds have not been examined. We assessed the current and historic distributions of beaver ponds and other coho salmon rearing habitat in the Stillaguamish River, a 1,771-km2 drainage basin in Washington and found that the greatest reduction in coho salmon smolt production capacity originated from the extensive loss of beaver ponds. We estimated the current summer smolt production potential (SPP) to be 965,000 smolts, compared with a historic summer SPP of 2.5 million smolts. Overall, current summer habitat capacity was reduced by 61% compared with historic levels, most of the reduction resulting from the loss of beaver ponds. Current summer SPP from beaver ponds and sloughs was reduced by 89% and 68%, respectively, compared with

historic SPP. A more dramatic reduction in winter habitat capacity was found; the current winter SPP was estimated at 971,000 smolts, compared with a historic winter SPP of 7.1 million smolts. In terms of winter habitat capacity, we estimated a 94% reduction in beaver pond SPP a 68% loss in SPP of sloughs, a 9% loss in SPP of tributary habitat, and an overall SPP reduction of 86%. Most of the overall reduction resulted from the loss of beaver ponds. Our analysis suggests that summer habitat historically limited smolt production capacity, whereas both summer and winter habitats currently exert equal limits on production. Watershed-scale restoration activities designed to increase coho salmon production should emphasize the creation of ponds and other slow-water environments; increasing beaver populations may be a simple and effective means of creating slow-water habitat.

Reid, K. A. 1952.
Effects of beaver on trout waters.
Maryland Conservation. 29:21-23.
Presents evidence that beaver ruin trout fishing by warming, silting, and blocking streams with their dams. "Where valleys are narrow and stream gradients steep, damage will be least. Where valleys are broad, gradients slight and water already near the critical temperature from the outflow from natural ponds and swamps, the damage will be greatest. Unfortunately it is in the latter type of habitat that beaver thrive and multiply. The only general exception to the ill effects of beaver on trout is in the high country of the western mountains. Here, with the source of the streams in eternal snow, the water may be too cold and the beds too steep and shallow for optimum growth of trout. By warming and ponding the water, trout are often benefited since increased acidity and increase of trash fish are negligible factors here. But elsewhere beaver and trout do not mix well for long."

Stevens, C. E., C. A. Paszkowski and G. J. Scrimgeour. 2006.
Older is better: beaver ponds on boreal streams as breeding habitat for the wood frog.
Journal of Wildlife Management. 70:1360-1371.
Succession of stream ponds mediated by beaver (Castor canadensis) damming and foraging in riparian zones may contribute to changes in amphibian populations. Our study examined the use of beaver ponds by the wood frog (Rana sylvatica) in a network of boreal streams in west-central Alberta, Canada. We quantified relations between breeding populations of wood frogs estimated from call surveys and pond age and riparian canopy cover, and we compared an index of juvenile recruitment to metamorphosis estimated with pitfall trap captures between new (< 10 yr) and old (> 25 yr) beaver ponds. We also conducted an in-pond enclosure experiment to determine if differences in physicochemical conditions of new versus old ponds influenced larval performance. Regression and Akaike's Information Criterion model averaging indicated that both density and calling intensity of male wood frogs at beaver ponds had a negative relationship with percent riparian canopy cover and had a positive relationship with pond age. The best a priori statistical models, however, included riparian canopy cover rather than pond age as a significant covariate. Old ponds had reduced riparian canopy and greater abundance of submergent vegetation, thermal degree-days, and dissolved oxygen concentrations compared to newly formed ponds. While survival of larval wood frogs in enclosures did not differ between pond age classes, growth and development rates in old ponds were greater than in new ponds. In addition to warmer water in old ponds, results from a laboratory experiment suggest that higher concentrations of dissolved oxygen characteristic of old ponds can enhance larval growth rates.

Older beaver ponds may support more breeding wood frogs due to adult selection for open-canopy ponds and the associated larval environments favourable for high rates of juvenile recruitment. Forest management that protects beaver and their food supplies may also promote healthy populations of boreal amphibians.

Suzuki, N. and B. C. McComb. 2004.
Associations of small mammals and amphibians with beaver-occupied streams in the Oregon Coast Range.
Northwest Science. 78:286-293.
We examined the association between stream reach and riparian conditions influenced by beavers with capture rates of small mammals and amphibians. We compared vegetation structure and capture rates of small mammals and amphibians between stream reaches occupied by beaver and unoccupied reaches in 5 streams in the Oregon Coast Range. Percent cover by stinking currant and all shrubs combined was lower at occupied than unoccupied reaches. Cover by elderberry, grasses, and sedges was higher at occupied than unoccupied reaches. Capture rates of individual species of small mammals and amphibians did not differ between beaver-occupied and unoccupied reaches (P >0.1). However, capture rates of species typically found in either early successional stages or ponds were higher in beaver-occupied areas. For instance, combined capture rates for 3 species of microtine voles were consistently higher at occupied than at unoccupied reaches (P 0.1). Further, variability in capture rates was higher among occupied than unoccupied reaches for 5 species of small mammals (P 0.1). We hypothesize that the high variability in capture rates is associated with more diverse vegetative and physical characteristics at beaver-occupied reaches. We also hypothesize that analyses conducted at larger spatial scales, including whole watersheds, may reveal contributions of beaver to riparian area heterogeneity and vertebrate diversity.

Wilkinson, T. 2003.
The benefits of beavers.
National Parks.
Beavers were considered extinct in the beginning of the 20th century. Their comeback in the United States and Canada is considered one of the greatest successes of conservation programs. These large industrious rodents create wetlands and marshy areas that provide habitat for hundreds of species. Beavers are famous for their prowess at building dams and engineering wetlands. These shy aquatic mammals can be found in the national parks of Alaska and southwest towards the Rio Grande. They live in domed lodges and weigh about 65 pounds. They breed in winter and give birth to kits in the spring. These slow moving mammals live mostly in water and on land are vulnerable to predators. Beaver experts confirm that these animals were once abundant and suffered radical depletion due to commercial fur trapping. The decline in beaver population caused drying of wetlands and expansion of meadows and forests. With the efforts to enhance riparian habitat, beavers were reintroduced. They break up landscape and affect the homogeneity of species by producing aquatic habitat. Though beavers cause floods, their marshes protect adjacent landscapes from the effects of flash floods. Numerous bird species including songbirds, amphibians, reptiles, aquatic insects, and fish draw benefits from the presence of beavers. Beaver ponds and dams act as filters capturing silt and other impurities. They can challenge humans by toppling trees in city parks and backyards. The floods in basements, roads, and croplands caused by their handiwork result in severe property damage. As

a nonlethal method of management, nontoxic chemicals are being used to repel these animals. Beavers scent-mark their territories and use unique ways of communication. They slap their flat tails against water surfaces as in alarm to intruders. Like wolves, beavers are cooperative breeders. They feed on a variety of trees, preferably aspen. During spring and fall, when leaves are not available, they feed on tree bark and when their food supply becomes less, the colony moves on. Efforts should be made to understand their abundance, distribution, and critical habitat needs, which help in the recovery of these charismatic animals.

Zimmerman, F. R. 1943.
Water levels in relation to fur bearers and waterfowl in central Wisconsin.
Wisconsin Conservation Bulletin. 8:23-26.
Flowages created by Federal aid have provided environment for fur animals and for water, marsh, and shore birds, have reduced fire hazards, and raised water tables. Benefits to wildlife on 35 flowages are discussed, and recommendations are made as to management of beavers, muskrats, and waterfowl; as well as of water levels. Bibliography of 7 titles.

Damage

Adams, D., B. Wigley, C. N. Owen, D. L. Adams and T. B. Wigley. 1984.
Inefficacy of a deer repellent on beavers.
Wildlife Society Bulletin. 12:405-408.

[Anonymus, 1998 #195]

Beier, P. and R. H. Barrett. 1987.
Beaver habitat use and impact in Truckee River Basin, California.
Journal of Wildlife Management. 51:794-799.
Stepwise logistic regression was used to identify factors important for habitat use by beavers on streams. Increasing stream width and depth and decreasing gradient had the strongest positive effects on habitat use; food-availability variables added little explanatory power. Some abandoned colony sites appeared to have been located on physically-unsuitable habitat, whereas others appeared to be physically-suitable sites abandoned due to resource depletion. The fact that few unused or uncolonized reaches were misclassified as suitable habitat suggests that suitable habitat has been saturated. Impact of beaver on woody plants was assessed for 8 forage species. Local extinction of quaking aspen (Populus tremuloides) and black cottonwood (P. trichocarpa) occurred on 4-5% of stream reaches. Willow (Salix spp.) showed good vigor despite heavy use in most reaches.

Bhat, M. G., R. G. Huffaker and S. M. Lenhart. 1993.
Controlling forest damage by dispersive beaver populations: Centralized optimal management strategy.
Ecological Applications. 3:518-530.

Bhat, M. G. 1992.
Controlling Wildlife Damage By Diffusing Beaver Population: A Bioeconomic Application of The Distributed Parameter Control Model.

Dissertation Abstracts International. Section A: Humanities and Social Sciences. 53:898-126.
The beaver population in the Southeastern United States has caused severe damage to valuable timber land through dam-building and flooding of bottom-land forest. The low beaver pelt price in the Southeast has failed to stimulate adequate trapping pressure, resulting in increased beaver damage on private timber lands. Since the beaver population is mobile, extermination of beavers from affected parcels results in migration of beavers from neighboring less controlled parcels to controlled parcels. This backward migration of beavers from uncontrolled habitat to controlled habitat imposes a negative diffusion externality on the owners of controlled parcels because they incur the cost of trapping immigrating beavers. This externality is likely to provide not enough incentive for control of beaver population on the part of individual land owners, causing a wedge between social and private needs for controlling beaver population. This study attempts to develop a bioeconomic model that incorporates dispersive population dynamics of beavers into the design of a cost-minimizing trapping strategy. The model simulates the area-wide damage control strategy in a situation where all the land owners in a given habitat share common interest of controlling beaver nuisance, and collectively agree to place the control decision in the hands of a public agency. The public manager attempts to minimize the present value combined costs of beaver damage and trapping over a finite period of time subject to spatiotemporal dynamics of beaver population. The time and spatial dynamics of beaver population is summarized by the parabolic diffusive Volterra-Lotka partial differential equation. The cost-minimizing trapping strategy requires that the marginal damage savings from the beavers trapped at each location equal the marginal costs of trapping. The optimality system for this problem that characterizes the optimal trapping rates is solved numerically. Finally, the empirical simulation of the model generated discrete values for the optimal beaver densities and trapping rates. The sensitivity analysis indicates that increase in the damage potential of beavers could substantially increase the discounted cost, whereas the increase in beaver trapping cost adds marginally to the total cost, conserving more beavers.

Bullock, J. F. and D. H. Arner. 1985.
Beaver damage to nonimpounded timber in Mississippi.
Southern Journal of Applied Forestry. 9:137-140.

Chabreck, R. H. 1958.
Beaver-forest relationship in St. Tammany Parish, Louisiana.
Journal of Wildlife Management. 22:179-183.
Plot sampling along streams occupied by beaver revealed that beaver used 22 woody plant spp. Sweetgum, sweetbay, spruce pine, and loblolly pine received heaviest use and were believed to be of greatest value to beaver. Many herbaceous plants were eaten in summer. On the plots, beaver barked 24% and cut down 18% of the woody plants present. The plants cut down were very small and of little significance to forestry. Less than 2% of the plants died from girdling. Most hardwoods, when barked, became susceptible to decay. Pine, when barked, became more vulnerable to fire damage and to attack by insects. Local beavers build few dams, but water impounded behind 1 beaver dam killed 20,647 bd. ft. of merchantable pine.--Author.

Christ, J. C. 1959.
A study of yellow birch (*Betula lutea*) in the bogs of Itasca Park, Minnesota.
American Midland Naturalist. 61:480-484.

Evidence that excessive populations of deer and beaver in the park completely prevented reproduction of this valuable tree. In the park, yellow birch is restricted to bogs and does not occur in uplands as it does over the main part of its range.

Cook, F. A. 1940.
Beaver study reveals damage to timber, corn only negligible.
Mississippi Game and Fish. 4:4.
Trees cut are small and of little value. Damage by feeding on corn and by flooding lands is seldom so extensive as to cause complaint. Conditions for fishes and wildfowl have been improved. Native beavers show a decided preference for small streams and introduced animals seek such places if not put there at first. The paper contains notes on dams, dens, lodges, activities, foods (20 plants listed), and breeding.

Cox, W. T.
The beaver-friend of the forest.
American Forests. 46:446-450.
In checking erosion, holding back flood waters, building meadows, and checking forest fires, the beaver is a friend of the forest. General description (including original contributions) of the habits, life history, and economic value of the beaver. Most claims of damage are inspired by a desire to trap the animals for gain. Flooding can be prevented by putting through the dams at the desired level pipes that protrude several feet both above and below the structure; apparently the problem of closing these is beyond the beaver's powers.

Curtis, P. D. and P. G. Jensen. 2004.
Habitat features affecting beaver occupancy along roadsides in New York State.
Journal of Wildlife Management. 68:278-287 | 278-288.
Characterizing habitat features that influence beaver (Castor canadensis) occupancy along roadsides may have important implications for managing damage to roads Caused by beaver activity. We initiated this study to develop proactive and long-term approaches to deal with nuisance beaver along roadsides. From June to October 1997 and 1998, we sampled 316 roadside sites in New York state, USA-216 sites where beaver occupied the roadside area and 100 unoccupied sites. We used stepwise logistic regression to identify habitat variables associated with beaver occupancy along roadsides. We evaluated regression models through measures of sensitivity and specificity. The logistic function retained the percentage of roadside area devoid of woody vegetation, stream gradient, the interaction between these 2 variables, and stream width in the final model. Precluding beaver occupancy along highways would necessarily involve large-scale removal of woody vegetation that would be impractical in all but the most intensive management scenarios. However, beaver habitat assessment adjacent to roads max, be a useful tool for designing new highways, prioritizing culvert replacements, and developing proactive plans for beaver damage management.

D'Eon, R. G. 1995.
Beaver handbook: A guide to understanding and coping with beaver activity.
Northeast Science & Technology, Ontario Ministry of Natural Resources.

Beavers are an important part of North American ecosystems, but can also cause problems such as road washouts and flooded timberland. This handbook is intended to help resource managers and field staff in northern Ontario address problems related to beaver activity. The information in the handbook was gathered from a survey of people with experience and knowledge of beaver problems. It includes a review of beaver biology and behavior, beaver management practices in Ontario, and beaver control measures that have been found effective in certain situations. These measures include various types of screens or grills for preventing beavers from blocking culverts and road crossings, beaver fences, and beaver pond levellers.

Dieter, C. D. and T. R. McCabe. 1988.
Beaver crop depredation in eastern South Dakota.
The Prairie Naturalist. 20:143-146.

Donkor, N. T. and J. M. Fryxell. 1999.
Impact of beaver foraging on structure of lowland boreal forests of Algonquin Provincial Park, Ontario.
Forest Ecology and Management. 118:83-92.
The authors examined the effects of beaver browsing on plant community structure at pond habitats in southern Algonquin Park, Ontario, Canada. Data show that the short-term selective foraging by beavers does not completely shift the woody plant community structure towards non-preferred species. Beavers likely increase the possibility of significant alteration in the structure and composition of boreal forests through composite effects of increased beaver populations and damming and flooding activities. pcp.

Enck, J. W., N. A. Connelly and T. L. Brown. 1996.
Public Attitudes Toward Wildlife and Its Accessibility. Public Attitudes Toward Beaver and Beaver Management: Management Response to Beaver Complaints in WMU 21.
New York [State]. Department of Environmental Conservation. Annual Report. 1996:44.
Information is synthesized from a reanalysis of three previous studies of stakeholder's (general public, landowners, and highway superintendents) beaver-related attitudes and experiences in New York (Purdy and Decker 1985, Enck et al. 1988, Enck et al. 1992). Regression models were developed to predict acceptance of beavers and acceptance of actions to address nuisance beaver problems.

Enck, J. W., N. A. Connelly and T. L. Brown. 1997.
Acceptance of beaver and actions to address nuisance beaver problems in New York.
Human Dimensions of Wildlife. 2:60-61.
The authors developed regression models predicting acceptance of beaver and acceptance of actions to address nuisance beaver problems using data from three mail surveys conducted in New York from 1985-1992. klf.

Enck, J. W. and T. L. Brown. 1996.
Citizen participation approaches for successful beaver management.
Human Dimensions of Wildlife. 1:78-79.
Wildlife managers in New York believe that new approaches are needed for encouraging and including public input into beaver management decisions. Successful citizen participation would

allow stakeholders to help develop the decision-making process as well as review and comment on the decision. pcp.

Fitzgerald, W. S. and R. A. Thompson. 1988.
Problems associated with beaver in stream or floodway management.
Proc. 13th Vertebrate Pest Conf.
Vertebrate Pest Conference. Proceedings. 13:190-195.

Hammerson, G. A. 1994.
Beaver (*Castor canadensis*): Ecosystem alterations, management, and monitoring.
Natural Areas Journal. 14:44-57.

Hedeen, S. E. 1985.
Return of the beaver, Castor canadensis, to the Cincinnati region.
The Ohio Journal of Science. 85:202-203.

Hoene, J. V. 1946.
North Woods beaver trouble.
American Forests. 52:538-539.
Thousands of dollars' worth of timber is being destroyed in Minnesota by beavers flooding woodland by blocking drainage ditches. Losses particularly heavy in the International Falls area are greater than those due to fire. Not only are standing trees killed but new growth is prevented. There is also considerable damage to roads. Trapping should be directed toward restricting beavers to hilly parts of the State where their presence is less harmful.

Jakes, A. F., J. W. Snodgrass and J. Burger. 2007.
Castor canadensis (Beaver) Impoundment Associated with Geomorphology of Southeastern Streams.
Southeastern Naturalist. 6:271-282.
We used a geographic information system (GIS) and logistic regression to investigate relationships between geomorphology and Castor canadensis (North American beaver) impoundment of lower-order, blackwater streams of a southeastern landscape. Using GIS, we divided streams into 632 500-m reaches and measured a set of geomorphic variables for each reach. Beavers were most likely to impound stream reaches crossed by roads with a gradient of ? 0.6 to 1.2% and watershed sizes of ? 2500 ha; reaches with watershed sizes < ? 500 ha or > 5000 ha were almost completely avoided. Gradient and road crossings contributed little to discrimination among impounded and unimpounded reaches, suggesting these variables had relatively small influences on beaver impoundment when compared to stream size. Our results indicate that GIS and geomorphic variables can be used to model the impoundment of streams over larger areas (e.g., the proportion of third-order watersheds impounded), but are less accurate at predicting the impoundment of individual reaches. However, the temporal dynamics of impoundment creation and abandonment will need to be incorporated into region-specific models before they can be used in ecosystem integrity assessment. (Author)

Jensen, P. G., P. D. Curtis, M. E. Lehnert and D. L. Hamelin. 2001.
Habitat and structural factors influencing beaver interference with highway culverts.

Wildlife Society Bulletin. 29:654-664 | 654.
The plugging of highway culverts by beavers (Castor canadensis) creates roadside impoundments that damage and sometimes flood the roadbed. Continually mitigating these problem sites requires considerable time, money, and resources from town, country, and state highway departments. The authors initiated this study to develop proactive and long-term approaches to deal with nuisance beavers along roadsides. Their specific objective was to compare culvert and habitat features at plugged and nonplugged culverts. From June to October 1997 and 1998, they sampled 216 roadside sites in New York state: 113 sites where beavers plugged the highway culvert and 103 sites where beavers did not plug the culvert but instead constructed an upstream or downstream dam. They used stepwise logistic regression (SLR) to identify key variables associated with plugged culverts. They evaluated classification rates of regression models with measures of sensitivity and specificity. For the combined data set, the logistic function retained culvert inlet opening area (m~2~) and stream gradient in the final model. Based on the two variables, the model correctly classified 79% of the sites. The results of the study indicated that installing oversized culverts would have the greatest influence on discouraging beaver plugging activity. Prorated over the service life of culverts, the installation of oversized culverts by highway departments may be more cost-effective than trapping, debris removal, or other short-term options to manage beaver damage to roads.

Jonker, S. A. 2003.
Values and attitudes of the public toward beaver conservation in Massachusetts.
Dissertation Abstracts International. Section B: Physical Sciences and Engineering. 64:2458-259.
In Massachusetts both human and beaver population levels are rising, beaver damage complaints are escalating, and beaver management options are restricted by the 1996 Wildlife Protection Act. Employing the Cognitive Value Hierarchy, this study enhances understanding of the public's value orientations, attitudes, and norms regarding human-beaver conflicts in Massachusetts. a mailback questionnaire was sent to a random sample of 5,563 residents in three geographic regions in Massachusetts and to residents who submitted a beaver complaint to Masswildlife in 1999/2000 (47.3% overall response rate). Results indicate that respondents believe beaver are an important part of the natural environment and they have a right to exist. Respondents also support some form of beaver management. Most respondents believe that beaver-related damage in Massachusetts has either increased or remained the same over the past five years, and indicated a preference for fewer beaver, regardless of experience with beaver damage. Respondents' attitudes are influenced by their experience with beaver damage, perceptions of extent of beaver damage, and tolerance of beaver. as severity of beaver damage was perceived to increase, respondents were more willing to accept lethal management/control of beaver. Respondents characterized by a "wildlife-use" orientation expressed a greater willingness to accept lethal action in response to beaver activity than respondents characterized by a "wildlife-protection" orientation. this relationship was partially mediated when respondents believed beaver damage had increased and/or they preferred to see fewer beaver in Massachusetts. Value orientations proved to be predictive of both attitudes and norms, thus validating the propositions of the Cognitive Value Hierarchy. Results confirm the importance of understanding and monitoring public attitudes, norms, perceptions, and tolerance in a longitudinal framework and coupling this information with biological data to determine trends in relation to increases in beaver populations and human-beaver conflicts. the concepts and causal relationships posed by the Cognitive Value Hierarchy can provide information to link attitudes,

norms, and values of wildlife stakeholder groups with socially acceptable management strategies. Replicating, expanding, and applying this framework to other wildlife species, and in different socio-political environments, can enhance the effectiveness and applicability of this theoretical perspective in understanding and resolving complex human-wildlife conflicts.

Jonker, S. A., R. M. Muth, J. F. Organ, R. R. Zwick and W. F. Siemer. 2006.
Experiences with beaver damage and attitudes of Massachusetts residents toward beaver.
Wildlife Society Bulletin. 34:1009-1021.
As stakeholder attitudes, values, and management preferences become increasingly diverse, managing human-wildlife conflicts will become more difficult. This challenge is especially evident in Massachusetts, USA, where furbearer management has been constrained by passage of a ballot initiative that outlawed use of foothold and body-gripping traps except in specific instances involving threats to human health or safety. Without regulated trapping, beaver (Castor canadensis) populations and damage attributed to them have increased. To develop an understanding of public attitudes regarding beaver-related management issues, we surveyed a random sample of Massachusetts residents in the spring of 2002 within 3 geographic regions where beaver are prevalent, as well as all individuals who submitted a beaver-related complaint to the Massachusetts Division of Fisheries and Wildlife in 1999 and 2000. We found that respondents held generally positive attitudes toward beaver. Respondents who experienced beaver-related problems tended to have less favorable or negative attitudes toward beaver than people who did not experience beaver damage. Attitudes toward beaver became increasingly negative as the severity of damage experienced by people increased. We believe continued public support for wildlife conservation will require implementation of strategies that are responsive to changing attitudes of an urban population and within social-acceptance and biological carrying capacities.

King, S. L., B. D. Keeland and J. L. Moore. 1998.
Beaver lodge distributions and damage assessments in a forested wetland ecosystem in the southern United States.
Forest Ecology and Management. 108:1-7.
Researchers determined the distribution and relative abundance of beaver and the amount, type, and distribution of beaver damage to mature trees and seedlings at Caddo Lake, Louisiana. Some form of damage was noted at one or more trees near 85% of the lodges. Intensive damage assessments around 35 lodges indicated that most damage to trees was restricted to peeling or stripping of bark. The results suggest that the effects of beaver damage on this baldcypress forest are minimal. klf.

Knudsen, G. J. 1951.
Wisconsin's eager beaver.
Wisconsin Conservation Bulletin. 16:11-15.
Although primarily a popular account, this article contains some original information on weights of large beaver, foods, breeding season, average number of young, density in regions of the state, preference for cut or burned areas, 1950 harvest (11,544), fur value, value of beaver work to forest and game, beaver damage to crops, roads, and trout streams. Beaver dams can cause over-heating of some types of trout streams, but not all types, and are not the only factor adversely affecting trout.

Laramie, H. A. J. 1963.
A device for control of problem beavers.
Journal of Wildlife Management. 27:471-476.
Beaver (Castor canadensis) dam-induced flooding has been controlled by use of beaver pipes in New Hampshire. These pipes, of fiber or wood and with multiple small openings along the length of the bottom portion, are placed through the dam and into the beaver pond. Height of outlet and length of pipe are factors in producing the desired water level. Installation of wire-mesh guards across the mouths of culverts tends to discourage rebuilding in culverts after the existing dam has been removed. New Hampshire now has 46 beaver dams with pipes installed and working well. All installations must be checked monthly and maintained as required. Beaver pipes are most useful on watersheds of less than 10 square miles. If culverts are involved, the maximum usable watershed is reduced to 4 square miles.

Lesica, P. and S. Miles. 2004.
Beavers indirectly enhance the growth of Russian olive and tamarisk along eastern Montana rivers.
Western North American Naturalist. 64:93-100.
Russian olive and tamarisk are introduced woody plants invading western North American riparian communities. Beavers can play an important role in structuring these communities by removing the dominant cottonwood trees. Our study explored the way in which beavers interact with cottonwood, Russian olive, and tamarisk along 4 rivers on the Great Plains of eastern Montana. We sampled cottonwood stands that supported populations of 1 or both exotic species, recording beaver damage and density in addition to size and age of cottonwood, Russian olive, and tamarisk. In stands where beaver had been present, they felled an average of 80% of cottonwood trees while rarely using Russian olive or tamarisk. Beaver foraging was apparent in nearly 90% of stands within 50 m of the river channel but only 21% of stands farther away, creating a sunny corridor along the river channel that may increase the invasive potential of Russian olive and tamarisk. Growth rates of both Russian olive and tamarisk were substantially higher where beavers had reduced the cottonwood canopy cover. Managers wishing to reintroduce beavers should consider the potential effect on invasive exotic plants.

Loker, C. A., D. J. Decker and S. J. Schwager. 1999.
Social acceptability of wildlife management actions in suburban areas: 3 cases from New York.
Wildlife Society Bulletin. 27:152-159 | 152.
Despite notable successes, wildlife damage management in suburban situations is widely perceived as difficult because of the vocal resistance of some suburban residents to many mitigation measures. We examined suburban residents' experiences with, concerns about, and acceptance of management actions for white-tailed deer (Odocoileus virginianus), beaver (Castor canadensis), or Canada geese (Branta canadensis) in three areas of New York state. We considered four types of interventions which represented degrees of invasiveness to the animals of concern: human behavior modification, nonlethal-noninvasive, nonlethal-invasive, and lethal. Results demonstrated that residents' concerns about wildlife were elevated by increasingly severe problem experiences. In addition, residents' acceptance of invasive and lethal methods to resolve wildlife problems in suburban areas was higher than many wildlife managers might expect. Contrary to our predictions, acceptance of invasive and lethal methods was more strongly related

to concerns about nuisance and economic damage issues than to concerns about health and safety issues. Our results provide useful information to wildlife professionals for management planning and communication regarding problem-causing wildlife in suburban areas.

Maestrelli, J. R. 1990.
Urban animal damage control in California.
Proc. Vertebr. Pest Conf.
Proc. Vertebr. Pest Conf. No. 14. 156-159. University of California.

Martinsen, G. D., E. M. Driebe and T. G. Whitham. 1998.
Indirect interactions mediated by changing plant chemistry: beaver browsing benefits beetles.
Ecology. 79:192-200.
The authors document an indirect interaction between beavers and leaf beetles, mediated by changing plant chemistry of their cottonwood hosts. Resprout growth from stumps and roots of beaver-cut trees contained twice the level of defense chemicals as normal juvenile growth. Leaf beetles are attracted to this resprout growth. klf.

Masslich, W. J., J. D. Brotherson and R. G. Cates. 1988.
Relationships of aspen (Populus tremuloides) to foraging patterns of beaver (Castor canadensis) in the Strawberry Valley of central Utah.
Great Basin Naturalist. 48:250-262.

McKinstry, M. C. and S. H. Anderson. 1999.
Attitudes of private-and public-land managers in Wyoming, USA, toward beaver.
Environmental Management. 23:95-101.
Researchers sent a mail survey concerning management of beaver in Wyoming to 5265 private-land managers and 124 public land managers in 1993. Primary concerns about beaver damage included, in order of decreasing importance, blocked irrigation ditches; girdled timber; blocked culverts; and flooded pastures, roads, crops, and timber. Primary benefits that landowners believed resulted from beaver were in order of importance, elevated water tables, increased riparian vegetation, and increased stock-watering opportunities. Perceived benefits and detriments of beaver were similar for managers of public and private holdings. klf.

Moen, R., J. Pastor and Y. Cohen. 1990.
Effects of beaver and moose on the vegetation of Isle Royale National Park.
Alces. 26:51-63.

Muller-Schwarze, D., B. A. Schulte, L. Sun, A. Muller-Schwarze and C. Muller-Schwarze. 1994.
Red maple (Acer rubrum) inhibits feeding by beaver (Castor canadensis).
Journal of Chemical Ecology. 20:2021-2034.

Naiman, R. J., C. A. Johnston and J. C. Kelley. 1987.
Ecosystem alteration of boreal forest streams and wetlands by beaver.
Ecological Society of America. Bulletin. 68:376.

Naiman, R. J. and C. A. Johnston. 1990.

Browse selection by beaver: effects on riparian forest composition.
Canadian Journal of Forest Research. 20:1036 | 1036-1043.

Naiman, R. J., G. Pinay, C. A. Johnston and J. Pastor. 1994.
Beaver influences on the long-term biogeochemical characteristics of boreal forest drainage networks.
Ecology. 75:905-921.

Packard, F. M. 1942.
Wildlife and aspen in Rocky Mountain National Park, Colorado.
Ecology. 23:478-482.
Aspen the only abundant deciduous tree in the Park is undergoing a decline due to infection by a number of fungi and to attacks by animals. These not only cause direct, but also indirect, damage through facilitating entrance of fungal spores. The elk, mule deer, and beaver are the most prominent species affecting the welfare of aspen, but small mammals are of some, and woodpeckers, especially sapsuckers, of considerable, importance. Extirpation of the aspen is foreseen.

Payne, N. F. and R. P. Peterson. 1986.
Trends in complaints of beaver damage in Wisconsin.
Wildlife Society Bulletin. 14:303-307.

Parsons, G. and M. Brown. 1978.
Effect of a four-year closure of trapping season for beaver in Fulton County.
New York Fish and Game Journal. 25:23-30.
Trapping for beaver in Fulton County was prohibited from 1969 to 1972, and the effects of the closure on the beaver population were evaluated. A substantial increase in beaver abundance insued, as evidenced by a calculated gain in the number of active colonies from 45 to 184. Beaver damage coplains also increased, plugging of road culverts being the principal type, but unil the number of colonies exceeded 150 the cost of servicing complaints was considered reasonable. It was concluded that an occupancy of 30 to 40 per cent of the potential colony sites would be desirable and that trapping may be permitted under regulations designed to maintain the beaver population at that level.

Payne, N. F. 1989.
Population dynamics and harvest response of beaver.
Proceedings of the Fourth Eastern Wildlife Damage Control Conference. 127:127-132.
The author discusses beaver population control and various aspects of beaver life history. Habitat use, territoriality, colony size, dispersal, reproduction, mortality, and population response to harvesting are investigated in this paper.

Perry, C. 1945.
Beaver crisis in the Northeast.
American Forests. 51:72-73.
The "seamy side" of beaver restoration, including destruction of trees intended for reforestation, damage to trout streams, flooding of highways, and interference with city water supplies.

Conservation officers quoted to the effect that there is little room for beavers in Massachusetts. Recent history in New York from a publication already noticed in WILDLIFE REVIEW (32, Nov. 1941, pp. 40-41). The statement is rather strong but the recommendations boil down to management. Conclusions: "Beavers may be 'friends of the forest,' but in the Northeast they certainly are not friends of the farmer, the railroad man, the highway engineer, or the lumberman; in many areas they are 'misplaced weeds.' The big problem is to keep them in locations where they belong. But it is doubtful if this can be accomplished short of immense expense, or without increased controlled trapping and transplanting of many areas remote from civilization, or through concentrated use of beavers on flood control and water conservation projects as is now done in some regions of the country."

Pietsch, L. R. 1956.
The beaver in Illinois.
Illinois State Academy of Science. Transactions. 49:193-201.
History, status, and recent catches. Beavers were nearly gone in Ill. by 1860 but some persisted until 1912. Introductions began in 1929. Some beavers came in from adjacent states. By 1950, when the population was about 3,565, there were beavers in 45 counties; by 1954 they were in 55 of the 102 counties of Ill. Complaints of crop and other damage led to transplanting. Trapping for fur began in 1951. Catch declined steadily from 659 in 1951 to 250 in 1955 although population was increasing. Reasons advanced for decline of catch are: 1. Beaver season is separate from that for other fur animals. 2. Trapping and handling is difficult. 3. Price of pelts is low, around $5.00.

Purdy, K. G., D. J. Decker and R. A. Malecki. 1987.
Highway superintendents' tolerance of beaver damage in New York.
Transactions of the Northeast Section of the Wildlife Society. 44:72-76.

Reid, K. A. 1952.
Effects of beaver on trout waters.
Maryland Conservation. 29:21-23.
Presents evidence that beaver ruin trout fishing by warming, silting, and blocking streams with their dams. "Where valleys are narrow and stream gradients steep, damage will be least. Where valleys are broad, gradients slight and water already near the critical temperature from the outflow from natural ponds and swamps, the damage will be greatest. Unfortunately it is in the latter type of habitat that beaver thrive and multiply. The only general exception to the ill effects of beaver on trout is in the high country of the western mountains. Here, with the source of the streams in eternal snow, the water may be too cold and the beds too steep and shallow for optimum growth of trout. By warming and ponding the water, trout are often benefited since increased acidity and increase of trash fish are negligible factors here. But elsewhere beaver and trout do not mix well for long."

Roblee, K. J. 1984.
Use of corrugated plastic drainage tubing for controlling water levels at nuisance beaver sites.
New York Fish and Game Journal. 31:63-80 | 62-80.

Roblee, K. J. 1987.

The use of the T-culvert guard to protect road culverts from plugging damage by beavers.
3:25-33.

Siemer, W. F., T. L. Brown, S. A. Jonker and R. M. Nuth. 2003.
Attitudes Toward Beaver and Beaver Management: Results from Baseline Studies in New York and Massachusetts.

Snodgrass, J. W. 1994.
A conceptual view of the effects of beaver ponds on North American streams.
Ecological Society of America. Bulletin. 75:

Stephansky, B. A. 1950.
Nuisance beavers.
Michigan Conservation. 15:5-19.
In Michigan's Upper Peninsula beaver damage control has become a big problem since the last trapping season in 1946. The author describes types of damage and how they are remedied by livetrapping and moving beaver to other areas and by removal of dams.

Syphard, A. D. and M. W. Garcia. 2001.
Human- and beaver-induced wetland changes in the Chickahominy River watershed from 1953 to 1994.
Wetlands. 21:342-353.
Historically, anthropogenic activities have contributed to the direct loss of wetland area, mostly due to agriculture and urban land uses. Urbanization also indirectly impacts wetlands at a landscape scale through altered wetland hydrology and change in the spatial configuration of wetlands in a watershed. In addition, beaver (Castor canadensis) create and modify wetlands in a landscape. Because of recent increases in urbanization and rising beaver populations, a raster-based geographic information system (GIS) was used to analyze the combined effects of humans and beavers on wetland area and types in the Chickahominy River watershed from 1953 to 1994. Results of the study revealed that 29% of the land changed during the 41-year study period, and wetland conversion constituted seven percent of the total change. The major reason for wetland loss was the construction of two large water-supply reservoirs in the watershed, and most of the remaining wetland loss was due to urbanization. Wetland functions vary depending on wetland type, and the results of this study showed that 90% of the change in wetlands from 1953 to 1994 was a result of shifting between wetland types. Beaver-modified wetlands increased 274%, and beaver activity was responsible for 23% of the wetland change.

Vesall, D., R. Gensch and R. Nyman. 1947.
Beaver--timber problem in Minnesota's 'Big Bog.'.
The Conservation Volunteer. 10:45-50.
The area is described; it was futilely drained for agriculture in 1915; about two decades later control dams were installed in the ditches to reduce the fire hazard and improve the habitat for waterfowl and other wildlife. Beavers increased and spread but have been trapped annually since 1939 except in 1940 and 1944. The population has remained at about one active colony to each 1.3 miles of ditch. Greater rainfall has been the main factor in increasing damage to timber by flooding. Location and structure of beaver dams are set forth; 77 percent of the dams were in use

at the time of the study. There were about 3 dams to a colony. Damage to timber was observed on about 29 acres for each mile of ditch; roads used for logging, patrol, and fire-fighting were inundated or undermined. Timber killed by the beavers would have had a market value of 4,651 per mile of ditch. The annual timber production is worth nearly three times that of beaver pelts. Intangible values of the animals are noted and their consideration in management plans suggested.

Welsh, R. G. and D. Muller-Schwarze. 1989.
Experimental habitat scenting inhibits colonization by beaver, Castor canadensis.
Journal of Chemical Ecology. 15:887-893.

Wigley Jr., T. B. 1981.
A model of beaver damage and control.
Mississippi State University.

Wigley, T. B. and E. E. Gbur. 1992.
Landowner characteristics associated with willingness to try beaver control.
Southern Journal of Applied Forestry. 16:138-139.

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. 123:23-128.
A study in northeastern Wisconsin in 1947 and 1948 indicates that drainage of beaver flowages may do more damage than did the original flooding through (1) decreasing the fertility of the soil, (2) increasing the fire hazard, (3) destroying fur animal habitat.

Wilkinson, T. 2003.
The benefits of beavers.
National Parks.
Beavers were considered extinct in the beginning of the 20th century. Their comeback in the United States and Canada is considered one of the greatest successes of conservation programs. These large industrious rodents create wetlands and marshy areas that provide habitat for hundreds of species. Beavers are famous for their prowess at building dams and engineering wetlands. These shy aquatic mammals can be found in the national parks of Alaska and southwest towards the Rio Grande. They live in domed lodges and weigh about 65 pounds. They breed in winter and give birth to kits in the spring. These slow moving mammals live mostly in water and on land are vulnerable to predators. Beaver experts confirm that these animals were once abundant and suffered radical depletion due to commercial fur trapping. The decline in beaver population caused drying of wetlands and expansion of meadows and forests. With the efforts to enhance riparian habitat, beavers were reintroduced. They break up landscape and affect the homogeneity of species by producing aquatic habitat. Though beavers cause floods, their marshes protect adjacent landscapes from the effects of flash floods. Numerous bird species including songbirds, amphibians, reptiles, aquatic insects, and fish draw benefits from the presence of beavers. Beaver ponds and dams act as filters capturing silt and other impurities. They can challenge humans by toppling trees in city parks and backyards. The floods in

basements, roads, and croplands caused by their handiwork result in severe property damage. As a nonlethal method of management, nontoxic chemicals are being used to repel these animals. Beavers scent-mark their territories and use unique ways of communication. They slap their flat tails against water surfaces as in alarm to intruders. Like wolves, beavers are cooperative breeders. They feed on a variety of trees, preferably aspen. During spring and fall, when leaves are not available, they feed on tree bark and when their food supply becomes less, the colony moves on. Efforts should be made to understand their abundance, distribution, and critical habitat needs, which help in the recovery of these charismatic animals.

Willging, B. and R. Sramek. 1989.
Urban beaver damage and control in Dallas-Fort Worth, Texas.
77-80. The Station.

Williams, R. M. 1959.
Beaver management in Idaho.
Idaho Wildlife Review. 11:6-9.
Beavers barely hung on in Idaho until given protection in 1897. Damage complaints grew with the population, and hundreds of beavers had to be caught by state men each year. In 1930s, a caretaker-trapper system was set up. Caretakers were allowed to pelt a specified number each year and also had to do live trapping and transplanting to handle damage complaints in their own areas. This worked well enough until recent years, when pelt price dropped, too few beavers were caught, and damage complaints rose. An open season was ordained, starting Oct. 1, 1957. Catch was about 24,000, or about 3 times as great as before. This reduced the number of colonies by 32% to 67% in different regions. It reduced but did not stop damage complaints. Only a few drainages were trapped too hard. Trapping seasons of 1958 and later are to have length of trapping period tailored to individual areas. The only real fear is that falling pelt prices may make it impossible to maintain the desired level of trapping. This would mean an expensive control program for the state.

Wittmann, K., J. J. Vaske, M. J. Manfredo and H. C. Zinn. 1998.
Standards for lethal response to problem urban wildlife.
Human Dimensions of Wildlife. 3:29-48.
Managers face limited options when dealing with problems created by urban wildlife. Destroying an animal that is perceived to be a nuisance is sometimes acceptable; at other times destroying the animal may be controversial. This paper uses the structural norm approach to develop standards for an agency's use of lethal response to problem urban wildlife. The paper describes three structural characteristics of public wildlife management norms (range of acceptable situations, norm intensity, and norm agreement) and shows how these standards may be affected by different situational contexts (impact severity) and different animal species. Three wildlife species (beavers, coyotes, and mountain lions) are examined across a continuum of situation contexts ranging from seeing wildlife in a residential area to an animal killing a person. For all three species, acceptability of destroying the animal increased as the impact severity of the human-wildlife interaction increased. For identical situations, however, acceptability of destroying an animal varied by species. Overall, the normative approach can effectively clarify the positions of constituents on wildlife management decisions for specific contexts and animal

species. Such information can decrease the risk of public controversy generated by general broad-based wildlife management policies.

Woodward, D. K. and R. B. Hazel. 1991.
Beavers in North Carolina: ecology, utilization, and management.
AG - North Carolina Agricultural Extension Service, North Carolina State University. The Service.

Dams (including construction, location, and as index to population size/density)

Albert, S. 1999.
The beaver and the flycatcher.
Endangered Species Bulletin. 24:16-17.
The author discusses the status of the North American beaver and the southwestern willow flycatcher. In a semi-arid region the beaver provides many benefits to other species. The flow of water is slowed down by the construction of beaver dam and this, in turn, allows the sediment to drop out and the water to percolate into the soil thus maintaining a high water table that will contribute to greater abundance and diversity of riparian vegetation and wildlife. In the 18th and 19th centuries the North American beaver populations started declining and the southwestern willow flycatcher species became endangered. With the help of beavers the Zuni Reservation in the semi-arid high desert of the Colorado Plateau began restoring riparian and wetland habitats. Small numbers of beavers were moved to streams containing abundant food. As the stream channel was incised it did not hold water year round. Existence of beavers in the area began to make a difference. The beaver dams helped slow down the flow of water and sediment to drop out. The water table began spreading over a wider area and thicker, lush, riparian vegetation began to be established. With better vegetation and habitat wildlife also improved in the riparian areas. With the open water pairs of flycatchers started establishing territories near the active beaver dams. The farmers who had initially complained about the beaver program benefited from the beaver dam water during the 1996 drought period.

Barnes, D. M. and A. U. Mallik. 1996.
Use of woody plants in construction of beaver dams in northern Ontario.
Canadian Journal of Zoology. 74:1781-1786.
The authors investigated newly formed beaver dams in northern Ontario to determine if beavers showed any plant preferences during dam construction. Data analysis indicated a selection of stems by beavers for dam construction based on size rather than species of plant.

Barnes, D. M. and A. U. Mallik. 2001.
Effects of beaver, Castor canadensis, herbivory on streamside vegetation in a northern Ontario watershed.
Canadian Field-Naturalist. 115:9-21.
Based on the life-form and their utility to beavers, the authors classified the riparian plants around beaver impoundments into five categories: alder-dam construction; trembling aspen-primary food; white birch and willows-secondary foods; shrubs--occasionally used for food and dam construction; and conifers-occasionally used for dam construction. They studied the influence of beaver herbivory on shoreline woody plants on randomly chosen dam sites: eight

recently active, seven recently abandoned, and eight old abandoned. Beavers concentrated their herbivory to within 20m of the impoundment edge. Twelve years after abandonment, trembling aspen had not yet re-established along old beaver dam sites.

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

Thirteen beaver colonies were investigated over 2 summer and fall periods. Live and dead-trapping, pond draining, ground observations, and dislodging with smoke were tested in obtaining basic colony-composition data. Only dead-trapping proved quick and reliable as an intensive census method. Beaver dams, scent mounds, size of main lodge, and number of lodges proved invalid as population indices. The lodge was not indicative of the colony; one colony may keep at least 3 different lodges in good repair. Colonies subsisting on aspen contained a significantly larger number of individuals (7.8) than colonies subsisting on willow (5.1). Over-wintering colonies av. 6.3 ± 1.3 beavers. Aerial coverage of drainages, using the food cache as an index, was both accurate and practical. There was always 1 food cache per colony and the cache, always surrounded by water, could be recognized easily. A reliable census of beaver populations in mountainous terrain may be obtained by counting the number of food caches in an area in late Sept. or Oct. and multiplying by av. number of beavers per winter colony.--Author.

Jensen, P. G., P. D. Curtis, M. E. Lehnert and D. L. Hamelin. 2001.
Habitat and structural factors influencing beaver interference with highway culverts.
Wildlife Society Bulletin. 29:654-664 | 654.
The plugging of highway culverts by beavers (Castor canadensis) creates roadside impoundments that damage and sometimes flood the roadbed. Continually mitigating these problem sites requires considerable time, money, and resources from town, country, and state highway departments. The authors initiated this study to develop proactive and long-term approaches to deal with nuisance beavers along roadsides. Their specific objective was to compare culvert and habitat features at plugged and nonplugged culverts. From June to October 1997 and 1998, they sampled 216 roadside sites in New York state: 113 sites where beavers plugged the highway culvert and 103 sites where beavers did not plug the culvert but instead constructed an upstream or downstream dam. They used stepwise logistic regression (SLR) to identify key variables associated with plugged culverts. They evaluated classification rates of regression models with measures of sensitivity and specificity. For the combined data set, the logistic function retained culvert inlet opening area (m~2~) and stream gradient in the final model. Based on the two variables, the model correctly classified 79% of the sites. The results of the study indicated that installing oversized culverts would have the greatest influence on discouraging beaver plugging activity. Prorated over the service life of culverts, the installation of oversized culverts by highway departments may be more cost-effective than trapping, debris removal, or other short-term options to manage beaver damage to roads.

Rebertus, A. J. 1986.
Bogs as beaver habitat in north-central Minnesota.
American Midland Naturalist. 116:240-245 | 240.

Although beavers frequently colonize lakes and streams that are adjacent to bog areas, few (Castor canadensis Huhl.) researchers have mentioned that beavers are capable of colonizing bogs that lack open water. In a l00-sq km area surveyed for beaver activity, one-third of the active colonies were in bogs and two-thirds were in lakes and rivers. From 1979 to 1981, the percent of colonies in bogs increased from 29% to 36%. Of 481 bogs in the study area, 200 (42%) had current or previous history of beaver activity (colony sites and work areas). At 101 bogs (21%), dam construction in seepage zones created flowages. Most impoundments were built at brushy minerotrophic sites. Moats were used at 99 bogs (21%), where beavers preferred sedge-moss cover and avoided tall shrub and wooded cover. The results show that bogs are suitable habitat for beavers.

Scheffer, V. B. 1941.
Management studies of transplanted beavers in the Pacific Northwest.
320-325.
"There are three important phases in management of the beaver in the Pacific Northwest: (1) Protecting the animal as a producer of fur, (2) removing it from highly cultivated lands, and (3) putting it to work as an agent in soil and water conservation in mountain meadows. In the present stage of land use in the Pacific Northwest, and for some years to come, to manage the beaver as a producer of fur is less important than to use it as a soil and water engineer." In the author's opinion, the open season for public trapping of beavers has had unfortunate results. He believes that trapping should be done only by trained game officers. The results of transplanting operations are summarized in a table. Three-fourths of the liberated colonies disappeared from the planting site in a few days or weeks. Eight principal reasons for this are suggested. The food relations of beaver colonies are discussed under four heads and the principal food trees of the animals are listed. Rates of tree cutting and lodge and dam construction are cited. The average amount of water stored by a colony at the end of the third year was about 15,000 cubic feet. Author's conclusions: "(1) The number of beavers dead-trapped where they are doing damage should be increased; (2) the causes that contribute to the failure of plantings are sufficiently well known that, by careful attention to the selection of sites, the game manager can establish 60 per cent of the colonies released; (3) considering the wide variety of habitats under which beavers are known to thrive, it is not practicable to determine before-hand, by the use of numerical standards only, the carrying capacity of a prospective planting site."

Sprules, W. W. 1940.
The effect of a beaver dam on the insect fauna of a trout stream.
American Fisheries Society. Transactions. 236-248.
"A qualitative and quantitative investigation of the distribution of aquatic insects in Mud Creek, Algonquin Park, Ontario, has been carried out during the summer months of the last 3 years. Samples of the population present were obtained by trapping the insects which emerged from 1 square yard of water surface. In the first season the field station described in this report was characterized by a rubble bottom and rapid flow of water. These conditions remained unaltered during the first part of the second season and the insect emergence for this period corresponded closely with that of the previous year. In early July, however, beavers constructed a dam across the stream flooding the riffle section which was under observation. The number of insects emerging immediately decreased as species dependent on a lotic environment were destroyed or forced to migrate. A few species were able to tolerate the new ecological conditions while a

numerically small group of species typically found in quiet water entered the area. In the third season the lentic nature of the habitat was continued and the change in the fauna was more complete since the total population approximated that of a slow-flowing, silted stretch of the stream."

Suzuki, N. and W. C. McComb. 1998.
Habitat classification models for beaver (Castor canadensis) in the streams of the central Oregon Coast Range.
Northwest Science. 72:102-110.
In Drift Creek Basin, Lincoln County, Oregon beavers built dams in areas with wide valley floors; narrow, low gradient streams; high grass and sedge cover; and low red alder and shrub cover. The authors used stream width, gradient, and valley floor width to develop a Habitat Suitability Index model for Drift Creek Basin. lgh.

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. 123:23-128.
A study in northeastern Wisconsin in 1947 and 1948 indicates that drainage of beaver flowages may do more damage than did the original flooding through (1) decreasing the fertility of the soil, (2) increasing the fire hazard, (3) destroying fur animal habitat.

Disease, including toxicology

Anderson, W. I., D. H. Schlafer and K. R. Vesely. 1989.
Thyroid follicular carcinoma with pulmonary metastates in a beaver (*Castor canadensis*).
Journal of Wildlife Diseases. 25:599-600.
An 11-yr-old female beaver (Castor canadensis) died after a 3 1/2 mo course of intermittent diarrhea, lethargy and anorexia. A postmortem examination revealed both a necrotizing ulcerative colitis and bilaterally enlarged thyroid glands. Histologically, the necrotizing colitis was similar to that caused by canine or feline parvovirus. Thyroid glands were multilobulated. Lobules were composed of irregularly arranged, variably sized follicles, some of which contained colloid. Follicles were lined by a pleomorphic population of tall cuboidal to columnar epithelial cells. Capsular invasion was present. Similar cells, forming follicles were present within the pulmonary parenchyma. This is the first documented case of a thyroid follicular carcinoma with pulmonary metastases in a beaver.

Butner III, C. H. and D. C. Ashley. 1987.
A survey for parasites of beaver (*Castor canadensis*) from northwest Missouri.
Missouri Academy of Science. Transactions. 21:149.

Brakhage, G. K. and F. W. Sampson. 1952.
Rabies in beaver.
Journal of Wildlife Management. 16:226. Missourie Department of Conservation.

Reports a rabid beaver from near Columbia, Missouri. The beaver attacked a farm dog.

Carlson, B. L., D. Hill and S. W. Nielsen. 1983.
Cutaneous papillomatosis in a beaver.
American Veterinary Medical Association. Journal. 183:1283-1284.

Cullen, C. L. 2003.
Normal ocular features, conjunctival microflora and intraocular pressure in the Canadian beaver (Castor canadensis).
Veterinary Ophthalmology. 6:279-84.
OBJECTIVE: The aim of the study was to assess the ocular features, normal conjunctival bacterial and fungal flora, and intraocular pressure (IOP) in the Canadian beaver (Castor canadensis). SAMPLE POPULATION: Sixteen, apparently healthy beavers with no evidence of ocular disease, and live-trapped in regions throughout Prince Edward Island. PROCEDURES: The beavers were sedated with intramuscular ketamine (12-15 mg/kg). Two culture specimens were obtained from the ventral conjunctival sac of both eyes of 10/16 beavers for aerobic and anaerobic bacterial and fungal identifications. The anterior ocular structures of all beavers were evaluated using a transilluminator and slit lamp biomicroscope. Palpebral fissure length (11/16 beavers), and horizontal and vertical corneal diameters (10/16 beavers) were measured. IOPs were measured in both eyes of 11/16 beavers using applanation tonometry. Both eyes of 3/16 beavers and one eye of 1/16 beavers were dilated using topical tropicamide prior to sedation to effect timely maximal dilation. Culture specimens and IOPs were not evaluated in these four animals. Indirect ophthalmoscopy was performed on 7/8 eyes of these four beavers. RESULTS: Conjunctival specimens from all eyes cultured positively for one or more isolates of aerobic bacteria. The most common isolate was Micrococcus spp. (five beavers; 9/20 eyes). Other isolates included a Gram-positive coccobacilli-like organism (four beavers; 7/20 eyes), Aeromonas hydrophila (three beavers; 4/20 eyes), Staphylococcus spp. (three beavers; 4/20 eyes), Gram positive bacilli (one beaver; 2/20 eyes), Enterobacter spp. (two beavers; 2/20 eyes), Streptococcus spp. (two beavers; 2/20 eyes), aerobic diphtheroids (one beaver; 1/20 eyes), and Pseudomonas spp. (one beaver; 1/20 eyes). Clostridium sordellii (one beaver; 1/20 eyes) and Peptostreptococcus spp. (one beaver; 1/20 eyes) were the sole anaerobic bacteria isolated. All conjunctival specimens were negative for growth of fungi. Ophthalmic examinations revealed the normal beaver eye and ocular adnexa included dorsal and ventral puncta, a vestigial third eyelid, and a circular pupil. Average palpebral fissure length was 9.36 mm (SD = 1.00) for both eyes. Mean horizontal and vertical corneal diameters of both eyes were 9.05 mm (SD = 0.64) and 8.45 mm (SD = 0.69), respectively. Mean IOP for the right and left eyes were 17.11 mmHg (SD = 6.39) and 18.79 mmHg (SD = 5.63), respectively. Indirect ophthalmoscopic examinations revealed normal anangiotic retinas. CONCLUSIONS: Gram-positive aerobes were most commonly cultured from the conjunctival sac of normal beavers, with Micrococcus spp. predominating. The overall mean IOP in ketamine-sedated beavers was 17.95 mmHg. The beaver, an amphibious rodent, has an anangiotic retina.

DeStefano, S., K. K. G. Koenen, C. M. Henner and J. Strules. 2006.
Transition to independence by subadult beavers (*Castor canadensis*) in an unexploited, exponentially growing population.
Journal of Zoology. 269:434-441.

We conducted a 4-year study of beavers Castor canadensis to compare the movements, survival and habitat of adults established in existing colonies to juveniles dispersing to new sites in a region with high beaver densities along a suburban-rural gradient. Estimates of annual survival were high for adult and juvenile beavers. Of nine known mortalities, seven (78%) were juveniles. Mortalities occurred during spring-summer, and none during fall-winter. There was a trend toward higher-to-lower survival along the suburban-rural gradient, respectively. Human-induced mortality (e.g. trapping and shooting) was higher in rural areas, whereas nonhuman-induced mortality (e.g. disease, accidents) was higher in suburban areas. Fifteen (14 subadults and one adult) beavers moved from natal colonies to other areas. The average dispersal distance for subadults was 4.5 km (SE=1.0) along streams or rivers, or 3.5 km (SE=0.7) straight-line point-to-point. Most dispersal movements were made in spring (April-June). In two cases, individual subadults made return movements from their dispersal sites back to their natal colonies. Dispersal sites tended to be in smaller, shallower wetlands or streams and in areas with higher overstorey canopy closure compared with natal colonies. Woody vegetation usually preferred by beavers for food tended to be less common at dispersal sites than at natal colonies. In regions with high densities of beaver, dispersing juveniles are likely to attempt to colonize lower quality sites. High densities of beavers also lead to more human-beaver conflicts and, in Massachusetts, the pest control management options in place during the past decade have been ineffectual at controlling population levels. Alternately, in regions with no beavers or very low densities and where reintroductions are being attempted, the landscape matrix surrounding release sites should include suitable sites for dispersing young to establish colonies.

Erickson, A. B. 1949.
The fungus (*Haplosporangium parvum*) in the lungs of the beaver (*Castor canadensis*).
Journal of Wildlife Management. 419 | 13:19-420 | 419-420.
This organism has been found in several rodents. The author believes that heavy infections are certain to be pathogenic.

Ernst, J. V., W. L. Cooper and M. J. Frydendall. 1970.
Eimeria sprehni Yakimoff, 1934, and *E. causeyi* sp. (Protozoa:Eimeriidae) from the Canadian beaver, *Castor canadensis*.
Journal of Parasitology. 56:30-31.

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. 37:492-497.
Feces from 62 beavers (Castor canadensis) in Massachusetts were examined by fluorescence microscopy (IFA) and polymerase chain reaction (PCR) for Microsporidia species, Cryptosporidium spp., and Giardia spp. between January 2002 and December 2004. PCR-positive specimens were further examined by gene sequencing. Protist parasites were detected in 6.4% of the beavers. All were subadults and kits. Microsporidia species were not detected. Giardia spp. was detected by IFA from four beavers; Cryptosporidium spp. was also detected by IFA from two of these beavers. However, gene sequence data for the ssrRNA gene from these two Cryptosporidium spp.-positive beavers were inconclusive in identifying the species. Nucleotide sequences of the TPI, ssrRNA, and P-giardin genes for Giardia spp. (deposited in

GenBank) indicated that the four beavers were excreting Giardia duodenalis Assemblage B, the zoonotic genotype representing a potential source of waterborne Giardia spp. cysts.

Fedynich, A. M., D. B. Pence and R. L. Urubeck. 1986.
Helminth fauna of beaver from central Texas.
Journal of Wildlife Diseases. 22:579-582. Wildlife Disease Association.

Flakas, K. G. 1953.
Wildlife pathology study: Beaver disease investigations.

Gamberg, M., B. Braune, E. Davey, B. Elkin, P. F. Hoekstra, D. Kennedy, C. Macdonald, D. Muir, A. Nirwal, M. Wayland and B. Zeeb. 2005.
Spatial and temporal trends of contaminants in terrestrial biota from the Canadian Arctic.
The Science of the Total Environment. 351-352:148-164.
Contaminants in the Canadian Arctic have been studied over the last twelve years under the guidance of the Northern Contaminants Program. This paper summarizes results from that program from 1998 to 2003 with respect to terrestrial animals in the Canadian Arctic. The arctic terrestrial environment has few significant contaminant issues, particularly when compared with freshwater and marine environments. Both current and historical industrial activities in the north may have a continuing effect on biota in the immediate area, but effects tend to be localized. An investigation of arctic ground squirrels at a site in the Northwest Territories that had historically received applications of DDT concluded that DDT in arctic ground squirrels livers was the result of contamination and that this is an indication of the continuing effect of a local point source of DDT. Arsenic concentrations were higher in berries collected from areas around gold mines in the Northwest Territories than from control sites, suggesting that gold mining may significantly affect arsenic levels in berries in the Yellowknives Dene traditional territory. Although moose and caribou from the Canadian Arctic generally carry relatively low contaminant burdens, Yukon moose had high renal selenium concentrations, and moose and some woodland caribou from the same area had high renal cadmium levels, which may put some animals at risk of toxicological effects. Low hepatic copper levels in some caribou herds may indicate a shortage of copper for metabolic demands, particularly for females. Similarities in patterns of temporal fluctuations in renal element concentrations for moose and caribou suggest that environmental factors may be a major cause of fluctuations in renal concentrations of some elements. Concentrations of persistent organochlorines and metals in beaver and muskrat from the Northwest Territories, and carnivores from across the Canadian Arctic were very low and considered normal for terrestrial wildlife. Two new classes of persistent fluorinated contaminants, perfluorooctane sulfonate (PFOS) and perfluoroalkyl carboxylates (PFCAs) were found in arctic carnivores and were most abundant in arctic fox and least abundant in mink. Although trace element concentrations in king and common eider ducks were low and not of toxicological concern, the number of nematode parasites in common eiders was positively correlated with total and organic mercury concentrations. Future research should focus on cadmium in moose and caribou, mercury in caribou, and emerging contaminants, with an effort to sample moose and caribou annually where possible to explore the role of naturally occurring cycles in apparent temporal trends.

Hacking, M. A. and L. Sileo. 1974.

Yersinia enterocolitica and *Yersinia pseudotuberculosis* from wildlife in Ontario.
Journal of Wildlife Diseases. 10:452-457 | 452-7.

Hamilton, D. A. and T. E. Davis. 1988.
An Assessment of the Occurrence of Baylisascaris procyonis (Nematoda) and Giardia spp. (Protozoa) in Raccoon (Procyon lotor) and Beaver (Castor canadensis) Populations in Missouri: Prevalence, Intensity and Geographical Distribution of Baylisascaris procyonis Infections in Raccoon (Procyon lotor) Populations in Missouri/Prevalence, Intensity and Distribution of Giardia spp Infections in Raccoon (procyon lotor) and Beaver (Castor canadensis) Populations in Missouri.
Missouri. Department of Conservation. Annual Report. 1988:14.

Hillis, T. L. and G. H. Parker. 1993.
Age and proximity to local ore-smelters as determinants of tissue metal levels in beaver (Castor canadensis) of the Sudbury (Ontario) area.
Environmental Pollution. 80:67-72.

Jackson, A. W. 1955.
Beaver resources management survey to gather data on parasites, disease, and reproduction.

Various correlations of body weight, tail size, crown-rump length and embryonic development is recorded.

Jellison, W. L., G. M. Kohls, W. J. Butler and J. A. Weaver. 1942.
Epizootic tularemia in the beaver, Castor canadensis, and the contamination of stream water with Pasteurella tularensis.
American Journal of Hygiene. 36:168-182.
"Field and laboratory studies are reported of an epizootic in beavers that affected numerous Montana streams from the late fall of 1939 to the late spring of 1940. P. tularensis was recovered from the tissues of dead beavers from 7 of the 8 areas involved. The facts that in the region concerned beavers are not known to harbor ticks, fleas, or other bloodsucking arthropods and that most of the deaths occurred at the season of the year when blood-sucking diptera were inactive suggested the improbability of arthropod transmission. The only positive evidence of tularemia infection in land animals living in close proximity to streams was obtained from field mice (Microtus pennsylvanicus) which were abundant in some of the areas and had been so recently in others. The tissues of 6 dead mice, 4 of them from the immediate vicinities of points where dead beavers were found, proved to be infected. "Apparent avenues of contact between tularemia-infected land animals and water animals are: (a) when stream water becomes contaminated with carcasses, tissue fragments, or infectious material from land animals (e.g., urine); and (b) when water animals leave the stream for food-getting and other activities on land. Water from 4 streams, one in each of 4 of the affected areas, was shown to be contaminated with P. tularensis, and in one stream contamination persisted for at least 33 days after any beavers were known to be present. No other streams were tested. Definite conclusions are impossible as to the primary source of the infection in beavers or the avenue or avenues by which they may acquire infection. The data obtained suggest two new questions concerning the epidemiology of tularemia: (a) the possibility that under favorable conditions epizootics may occur in local animal

populations without the aid of blood-sucking parasites, and (b) the possibility that P. tularensis-contaminated stream water may be an occasional source of human infection in this country." Bibliography of 8 titles.

Lang, B. Z. 1977.
Snail and mammalian hosts for *Fasciola hepatica* in eastern Washington.
Journal of Parasitology. 63:938-939.

Lawrence, W. H. and S. A. Graham. 1955.
Parasites and diseases of the beaver (Castor canadensis Kuhl): An annotated bibliography.

Chronological listing, with brief abstracts, of 52 publications or unpublished reports. Following this section, references are listed for each parasite or disease.

Lawrence, W. H. and S. A. Graham. 1955.
Parasites and diseases of the beaver (Castor canadensis Kuhl).
Michigan Wildlife. 2:6.

Margolis, B. E., M. S. Castro and R. L. Raesly. 2001.
The impact of beaver impoundments on the water chemistry of two Appalachian streams.
Canadian Journal of Fisheries and Aquatic Sciences. 58:2271-2283.
The authors measured the impacts of beaver impoundments on the water chemistry of two headwater streams on the Appalachian Plateau, an unnamed tributary to Herrington Creek (HR), and Mountain Run (MT). They measured acid-neutralizing capacity (ANC), pH, conductivity, discharge, temperature, and the concentrations of major ions, dissolved organic carbon (DOC), and trace metals in stream water upstream and 1 m, 10 m, and 100 m downstream of the beaver impoundments and at two locations, 147 m apart, in a tributary to HR that did not contain a beaver impoundment. There were significant differences in water chemistry upstream and downstream of the beaver impoundments at both MT and HR, but these differences were generally confined to the summer. During the summer, both beaver impoundments generated ANC and increased pH by acting as sinks for NO^3^~-~ and sources of NH^4^~+~, iron, and manganese. In addition, the beaver impoundment at MT was a sink for SO^4^~2-~ and the impoundment at HR was a source of DOC. The generation of ANC by beaver impoundments may be important to streams of this region where inputs of strong acids from atmospheric deposition are relatively high.

McKown, R. D., J. K. Veatch, R. J. Robel and S. J. Upton. 1995.
Endoparasites of beaver (Castor canadensis) from Kansas.
Helminthological Society of Washington. Journal. 62:89-93.

Monzingo, D. L., Jr. and C. P. Hibler. 1987.
Prevalence of Giardia sp. in a beaver colony and the resulting environmental contamination.
Journal of Wildlife Diseases. 23:576-585. Wildlife Disease Association.

Pascoe, G. A., R. J. Blanchet and G. Linder. 1996.
Food chain analysis of exposures and risks to wildlife at a metals-contaminated wetland.

Archives of Environmental Contamination and Toxicology. 30:306-318 | 306.
The daily intake of heavy-metal contaminants by members of the food chain in the Milltown Reservoir Sediments Superfund site in Montana was below or within the range of toxicity values for all the species evaluated. The range of toxicity values was the lower end of chronic toxicity data found in the literature for the same or similar species.

Rupprecht, C. E., J. Shaddock, M. Niezgoda, C. A. Hanlon, L. A. Orciari, J. E. Childs, J. T. McPherson and L. Hunter. 1998.
When size may matter: rabies in the beaver (Castor canadensis).
("Abstracts of the 47th Annual Wildlife Disease Association Conference, Madison, Wisconsin, August 9-13, 1998"). 9-13.

St. Amant, J. R. and T. B. Sheffy. 1982.
Mercury burdens in furbearers in Wisconsin (Pollutants from industry).
Journal of Wildlife Management. 46:1117-1120. Wildlife Society.

Objectives were to determine: (1) mercury burdens in mammals with food habits similar to those of piscivorous birds; (2) preferential binding sites of mercury in furbearers; (3) degree of correlation between mercury levels in furbearers and their prey and bottom sediment along particular drainage system; and (4) normal background levels of mercury in furbearers.

Stenlund, M. H. 1953.
Report of Minnesota beaver die-off, 1951-1952.
Journal of Wildlife Management. 17:376-377. Minnesota Division of Game and Fish.

Many beaver died during the winter, probably as many as were trapped. Some whole colonies were wiped out, others were not affected. The disease was widespread. Tularemia was diagnosed in some of the victims. Hundreds of muskrats reportedly died of tularemia in the fall of 1951, and several trappers contracted the disease.

Stuart, B. P., W. A. Crowell, W. V. Adams and D. T. Morrow, et al. 1978.
Spontaneous renal disease in beaver in Louisiana.
Journal of Wildlife Diseases. 14:250-253 | 250 | 250-3.
Interstitial nephritis was present in 13 of 25 adult beavers (Castor canadensis). Results of serum chemistry, serotyping, and culture for leptospires were compared with the extent of renal lesions. Although the pathogenesis of the nephritis was not determined, the survey provided baseline information on spontaneous renal disease in beavers.

Wren, C., H. MacCrimmon, R. Frank and P. Suda. 1980.
Total and methyl mercury levels in wild mammals from the precambrian shield area of south central Ontario, Canada.
Bulletin of Environmental Contamination and Toxicology. 25:100-105 | 100 | 100-5.

Wren, C. D. 1984.
Distribution of metals in tissues of beavers, raccoon, and otter from Ontario, Canada.
The Science of the Total Environment. 34:177-184 | 177-84.

Mercury and selenium concentrations were positively correlated in liver tissue of beaver, raccoon and otter from an undisturbed watershed in south central Ontario. Selenium accumulation in piscivorous mammals may represent a protective mechanism against methylmercury toxicity to animals exposed to high mercury levels in their diet. This paper also reports the levels of several other metals in tissues of three wild fur-bearing mammal species.

Dispersal, movements, and home range

Allred, M. 1981.
The potential use of beaver population behavior in beaver resource management.
Idaho Academy of Science. 17:14-24.

Atwood, E. L., Jr. 1938.
Some observations on adaptability of Mich beavers released in Missouri.
Journal of Wildlife Management. 2:165-166.
Beavers transplanted in 1928 and 1929 throve and spread to a distance of 80 miles. Due presumably to the swiftness of headwaters the movement been entirely downstream. Cornfields, sources of both food and dam mater appear to have been an important factor in fixing the location of colonie Natural foods (17 kinds listed) also are well utilized. The number of cuttings is proportional to the abundance of the plants within 100 feet of the stream bank.

Beer, J. R. 1955.
Movements of tagged beaver.
Journal of Wildlife Management. 19:492-493.
A small series of beaver was live trapped, ear tagged, and released at point of capture. Ten beaver were subsequently retaken. Adults were quite sedentary. Kits and yearlings were retaken in colonies as much as 51 miles from point of original capture.--James Beer.

Beier, P. and R. H. Barrett. 1989.
Beaver distribution in the Truckee River Basin, California.
California Fish and Game. 75:233-238.

Berghofer, C. B. 1962.
Movement of beaver.

Between 1945 and 1960, releases of 397 ear-tagged beaver were made in New Mexico. Twenty-seven of these were subsequently retrapped. The greatest distance from the release site of any retrapped beaver was 32 miles. The average distances traveled overland and downstream were 14 and 6 miles respectively. The average distance traveled downstream by {male}{male} was 8 while {female}{female} averaged 6. The average distance traveled overland was 16 and 9 for {male}{male} and {female}{female} respectively. Appromimately 55% of the retrapped beaver had moved overland. The above data indicate that adult beaver are more inclined to travel in search of new habitat than are the young. Males may be expected to travel farther than {female}{female}. Beaver moving overland may travel farther than those going downstream in spite of the convenience downstream travel affords.

Boyce, M. S. 1981.
Habitat ecology of an unexploited population of beavers in interior Alaska.
Proceedings of the Worldwide Furbearer Conference. 155-186.

Bradt, G. W. 1938.
A study of beaver colonies in Michigan.
Journal of Mammalogy. 19:139-162.
Report on research since 1929 as a basis for management by the Game Division of the Michigan Department of Conservation. Notes on trapping by improved aluminum alloy live-trap, and on handling and transporting beavers identification of sexes; and marking the animals by tagging and branding the tails. A careful study of the numerical composition of 57 beaver colonies gave an average of 5.1 animals per colony. The number is not closely correlated with those of lodges, bank burrows, or dams. The "typical" beaver colony consists of two parents, yearlings, and kits of the current year. The sexes exist in about equal numbers; there is a single litter of 3 or 4 young. The most important foods are aspen, maple, and willow, but a great variety plants are sampled, and aquatics are consumed to a considerable extent in summer. "The beavers studied cut between 200 and 300 trees each per year. One acre of poplar (aspen) should support an average beaver colony from 1 to 2.5 years, depending on circumstances. Yearlings are permitted to remain in the colony, but the two-year-old beavers leave or are driven from the home colony shortly before the birth of the second annual litter. Beavers do not always follow water courses during emigration, but may undertake long overland journeys. The emigration of the two-year-old beavers provides a method of dispersal, and tends to establish new colonies in areas not previously stocked with beaver. The size and composition of beaver colonies is such as to permit the efficient and economical use of food supplies adjacent to small bodies of water." Bibliography of 16 titles.

Bradt, G. W. 1947.
Michigan beaver management.

In 6 chapters the author discusses "History", "General Characteristics", "Population Studies", "Management", "Beaver Farming", and "Beaver vs. Trout Controversy." The chapter on population studies describes research methods, life history, behavior, and food. Management requires a method of censusing; measures of reproductive rate, mortality factors, and food supply; knowledge of the manner of dispersal; and means and authority for controlling the harvest by man. There are excellent, large photos and entertaining drawings.

Breck, S. W., K. R. Wilson and D. C. Andersen. 2001.
The demographic response of bank-dwelling beavers to flow regulation: a comparison on the Green and Yampa rivers.
Canadian Journal of Zoology. 79:1957-1964.
The authors assessed the effects of flow regulation on the demography of beavers (Castor canadensis) by comparing the density, home-range size, and body size of bank-dwelling beavers on two sixth-order alluvial river systems, the flow-regulated Green River and the free-flowing Yampa River, from 1997 to 2000. Flow regulation on the Green River has altered fluvial geomorphic processes, influencing the availability of willow and cottonwood, which, in turn, has influenced the demography of beavers. Beaver density was higher on the Green River (0.5-0.6

colonies per kilometre of river) than on the Yampa River (0.35 colonies per kilometre of river). Adult and subadult beavers on the Green River were in better condition, as indicated by larger body mass and tail size. There was no detectable difference in home range size, though there were areas on the Yampa River that no beavers used. The authors attribute the improved habitat quality on the Green River to a greater availability of willow. They suggest that the sandy flats and sandbars that form during base flows and the ice cover that forms over winter on the Yampa River increase the energy expended by the beavers to obtain food and increase predation risk and thus lowers the availability of woody forage.

Buech, R. R. 1988.
Environmental relations and adaptive strategies of beavers (*Castor canadensis*) in a near-boreal region.
49:University of Minnesota.

Busher, P. E. 1975.
Movements and activities of beavers, Castor Canadensis, on Sagehen Creek, California.
San Francisco State University.

Chubbs, T. E. and F. R. Phillips. 1994.
Long distance movement of a transplanted beaver, *Castor canadensis*, in Labrador.
Canadian Field-Naturalist. 108:366.

Davis, J. R. and D. C. Guynn. 1993.
Activity and Habitat Utilization of Beaver Colonies in South Carolina.
47:299-310.
Objectives were to describe monthly, seasonal, and yearly activities of beaver in the Piedmont of South Carolina, determine sizes of areas impacted by beaver, compare lake colony beaver activity to an adjacent stream colony, and describe habitat utilization by beaver in the Piedmont of South Carolina.

Davis, J. R., D. C. Guynn and G. W. Gatlin. 1994.
Territorial Behavior of Beaver in the Piedmont of South Carolina.
48:152-161.
Territorial behavior was evaluated for beaver in four study areas by monitoring scent marking and movements of adjacent colonies. An attempt was made to prove: expression of territorial behavior in the form of scent marking is density dependent; scent marking is seasonal; scent marking is related to woody forage availability; and scent mounds exhibit a "scent-fence" function.

Denney, R. N. 1952.
A summary of North American beaver management, 1946-1948.
28:
The first part of this paper is based on survey of literature and questionnaire returns from states and provinces. Major headings are: life history and habitat trends, populations, ecological effects (includes damage and relationships with trout), farms and refuges, trapping seasons and limits, size and value of harvest, and law enforcement problems. The second part of the paper presents

results of a live-trapping study in Colorado: fate of marked beavers, travels, sex ratio, weights, experimental transplanting by parachute. The paper should be a valuable source of many types of information on beavers, particularly because of the large amount of data from so many political units. 58 references.

DeStefano, S., K. K. G. Koenen, C. M. Henner and J. Strules. 2006.
Transition to independence by subadult beavers (*Castor canadensis*) in an unexploited, exponentially growing population.
Journal of Zoology. 269:434-441.
We conducted a 4-year study of beavers Castor canadensis to compare the movements, survival and habitat of adults established in existing colonies to juveniles dispersing to new sites in a region with high beaver densities along a suburban-rural gradient. Estimates of annual survival were high for adult and juvenile beavers. Of nine known mortalities, seven (78%) were juveniles. Mortalities occurred during spring-summer, and none during fall-winter. There was a trend toward higher-to-lower survival along the suburban-rural gradient, respectively. Human-induced mortality (e.g. trapping and shooting) was higher in rural areas, whereas nonhuman-induced mortality (e.g. disease, accidents) was higher in suburban areas. Fifteen (14 subadults and one adult) beavers moved from natal colonies to other areas. The average dispersal distance for subadults was 4.5 km (SE=1.0) along streams or rivers, or 3.5 km (SE=0.7) straight-line point-to-point. Most dispersal movements were made in spring (April-June). In two cases, individual subadults made return movements from their dispersal sites back to their natal colonies. Dispersal sites tended to be in smaller, shallower wetlands or streams and in areas with higher overstorey canopy closure compared with natal colonies. Woody vegetation usually preferred by beavers for food tended to be less common at dispersal sites than at natal colonies. In regions with high densities of beaver, dispersing juveniles are likely to attempt to colonize lower quality sites. High densities of beavers also lead to more human-beaver conflicts and, in Massachusetts, the pest control management options in place during the past decade have been ineffectual at controlling population levels. Alternately, in regions with no beavers or very low densities and where reintroductions are being attempted, the landscape matrix surrounding release sites should include suitable sites for dispersing young to establish colonies.

Dieter, C. D. and T. R. McCabe. 1989.
Habitat Use by Beaver Along the Big Sioux River in Eastern South Dakota.
Riparian Resource Manage. 135-140.
Habitat use by beavers Castor canadensis was investigated during 1985 and 1986 in grazed and ungrazed areas along the Big Sioux River in eastern South Dakota. Almost half (48%) of the trees in ungrazed areas were small (diameter at breast height < 7.5 cm), but a majority (58%) of the trees in grazed areas had large diameters (diameter > 30 cm). Beaver activity was evident on 280 of 2369 (11.8%) trees (diameter > 2.5 cm) and 756 of 7794 (9.7%) stems (diameter </= 2.5 cm) sampled. A greater proportion of trees were cut by beavers in ungrazed than in grazed areas. Beaver did not select tree species for cutting according to availability. Trees cut by beaver were significantly smaller in diameter than uncut trees. Mean distance from water of cut trees was less than for uncut trees. Over half (52%) of the trees damaged by beaver either resprouted or remained alive and standing.

Foster, D. R., G. Motzkin, D. Bernardos and J. Cardoza. 2002.

Wildlife dynamics in the changing New England landscape.
Journal of Biogeography. 29:1337-1357.
Aim: Over the past four centuries the eastern US has undergone remarkable landscape and land-use transformations involving deforestation, intensive agriculture, farm abandonment, reforestation and human population increase that have induced sweeping changes in wildlife assemblages, abundances, and distributions. This study compiles data on major wildlife species and seeks to identify broad population trends and to address both fundamental and applied questions regarding these long-term patterns. Location: The study encompasses the state of Massachusetts, which is broadly representative of the habitat conditions and landscape and cultural history of other New England states. Methods: A wide range of historical sources of data were used including town histories, newspaper and other popular accounts, scientific studies, museum collections, compiled trapping, bounty and harvest records, explorer accounts, and agency records. Statewide distribution maps and generalized population trends were assembled for individual species where practical, and major trends in species trajectories were identified. Emphasis was placed on mammals and birds for which data are readily available. Results: Although species exhibited highly individualistic long-term dynamics in response to habitat change and human pressure, six major trajectories of species changes are identified: (1) large mammals and birds that declined historically and increased recently, (2) open-land species that went from low to high abundance with the creation of open habitat but are in rapid decline today in the heavily wooded landscape, (3) species regionally extirpated or globally extinct, (4) species expanding their range from the west, north and south, (5) non-native, introduced species, and (6) persistent species not exhibiting major long-term trends. Currently, wildlife populations are changing at a remarkable rate leading to significant ecological impacts on the landscape and many other species, creating major conservation and management challenges, and generating novel and oftentimes significant conflicts with human values. Conclusions: The rate of historical and current changes in wildlife assemblages pose many scientific and conservation challenges, especially in this heavily forested but highly populated landscape. Historical data are fragmentary and oftentimes uncertain, modern information on wildlife populations is similarly incomplete, and small populations of species that are immigrating, expanding or declining from previously high levels pose major sampling problems; development of conservation and management plans for rapidly expanding populations of large woodland mammals (e.g. moose, coyote, deer, bears, beaver) and for declining populations of cherished species that are dependent on cultural landscapes generates conflicting directives; and educating, and modifying the behaviour of a human population that is living in but separated from nature is a difficult enterprise. The future is guaranteed to bring major dynamics in these historically novel species assemblages.

Fryxell, J. M. 1992.
Space use by beavers in relation to resource abundance.
Oikos. 64:474-478.

Fryxell, J. M. 2001.
Habitat suitability and source-sink dynamics of beavers.
Journal of Animal Ecology. 70:310-316.
1.Theory suggests that territorial species should share many of the same dynamical characteristics as metapopulations, including asynchronous local dynamics, potential for

stochastic extinction of the population when rates of successful dispersal fall below mortality risk, and critical importance of the ratio of suitable to unsuitable habitat for long-term persistence. These propositions were tested on a population of beavers in Algonquin Provincial Park, Ontario, which has been continuously monitored over 11 years. 2. Results showed that the total population was considerly less variable than local abundance at 14 beaver colonies, due to asynchrony among local populations. This suggests that local ecological interactions were more important in determining year-to-year variation in beaver numbers than broad-scale environmental processes, such as weather. 3. Of the local colonies, 20% were never abandoned over 11 years, although there was considerable turnover among adults. Offspring production exceeded adult abundance at five source colonies, which did not quite compensate for negative net production at nine sink colonies. These observations were consistent with predictions of spatially structured models of territoriality incorporating local variation in habitat suitability. Mean colony size and probability of recurrence from year-to-year were associated with local food availability, indicating that trophic interactions were important in determining local population dynamics. 4. The beaver population in Algonquin declined steadily over the study period, however, suggesting that spatial and demographic processes were insufficient to stabilize abundance over time. This is consistent with predictions of spatially structured models of territoriality in which suitable and unsuitable habitats are interspersed. It is hypothesized that long-term decline in habitat suitability is induced by acceleration of woody plant succession due to selective foraging by beavers.

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

Harris, H. T. 1991.
Habitat use by dispersing and transplanted beavers in western Montana.
40:Univ. of Montana.

Herr, J., D. Muller-Schwarze, F. Rosell and M.-S. D. 2006.
Resident beavers (Castor canadensis) do not discriminate between castoreum scent marks from simulated adult and subadult male intruders.
Canadian Journal of Zoology. 84:615-622.
Subadult intruding beavers (Castor spp.) could be expected to pose a higher threat than adults to territory holders because, unlike adults who usually own a territory, subadults need to acquire a territory and a mate to reproduce successfully. We tested the responses of territorial beavers (Castor canadensis Kuhl, 1820) to simulated intrusions by adult and subadult males. Territorial intrusion was simulated through scent playback experiments that exposed residents to castoreum from adult and subadult strangers simultaneously. We obtained responses from 13 resident beavers. Neither sniffing response nor physical or total responses differed between castoreum from adults and subadults. This was true for both sexes combined and separate. There was also no significant correlation between the mass of the scent donor and the response intensity. We found no evidence that territorial beavers responded differentially to castoreum scent marks from intruders of different ages. Either beavers consider all strange intruders as posing a high threat and hence do not treat them differentially or castoreum does not contain sufficient information to

allow beavers to discriminate between age classes. We suggest that rather than directly assessing intruders by means of intrinsic information contained in the scent mark, beavers assess their competitors through scent matching.

Hibbard, E. A. 1958.
Movements of beaver transplanted in North Dakota.
Journal of Wildlife Management. 22:209-211.
Recoveries were obtained from 18 of 155 ear-tagged beaver that were transplanted between 1947 and 1953. Seventeen animals were found to have moved an av. distance of 5.9 airline or 9.1 stream mi. An exceptional distance was covered by one beaver that traversed three drainages in 7 months to move 148 stream mi. or 67 airline mi.

Hiner, L. E. 1938.
Observations on the foraging habits of beavers.
Journal of Mammalogy. 19:317-319.
In Itasea State Park, Minn., where beavers, after extermination, were reintroduced in 1901 and had reached the stage of overpopulation by 1934. Then apparently the animals were forced to travel maximum distances for food. Observations of other writers in that respect and the author's findings cited. The average of the distances measured was 267 feet; the maximum 453. The longer hauls were down slopes. Bibliography of 5 titles.

Hodgdon, H. E. 1978.
Social dynamics and behavior within an unexploited beaver (*Castor canadensis*) population.
312:3614. University of Massachusetts.

DISSERTATION (PH.D.) - UNIVERSITY OF MASSACHUSETTS. STUDY BASED ON 6 YEARS OF OBSERVATIONS. 18 PAGES OF REFERENCES. SEX DETERMINATION BY EXAMINATION OF POLYMORPHONUCLEAR NEUTROPHIL LEUCOCYTES DISCUSSED.

Houston, A. E., M. R. Pelton and R. Henry. 1995.
Beaver immigration into a control area.
Southern Journal of Applied Forestry. 19:127-130.

Houston, A. E. 1998.
The beaver--a southern native returning home.
Proceedings of the Eighteenth Vertebrate Pest Conference. 12-17.
The author examined immigrant patterns of beaver from a 1,619 ha study area in west Tennessee. He removed resident beaver from the area, and for the next 40 months immigrants were captured within one month of immigration. Removal patterns of the resident population suggest that bounty systems may be ineffectual for protection of natural resources. Immigration was low (5.5 beavers) in June through September and higher (46.4 beavers) in October through May. klf.

Jackson, M. 1990.
Beaver dispersal in western Montana.

University of Montana.

Jaksic, F. M., J. A. n. Iriarte, J. E. Jim,nez and D. R. Mart¡nez. 2002.
Invaders without frontiers: cross-border invasions of exotic mammals.
Biological Invasions. 4:157-173.
[unedited] We address cross-border mammal invasions between Chilean and Argentine Patagonia, providing a detailed history of the introductions, subsequent spread (and spread rate when documented), and current limits of mammal invasions. The eight species involved are the following: European hare (Lepus europaeus), European rabbit (Oryctolagus cuniculus), wild boar (Sus scrofa), and red deer (Cervus elaphus) were all introduced from Europe (Austria, France, Germany, and Spain) to either or both Chilean and Argentine Patagonia. American beaver (Castor canadensis) and muskrat (Ondatra zibethicus) were introduced from Canada to Argentine Tierra del Fuego Island (shared with Chile). The American mink (Mustela vison) apparently was brought from the United States of America to both Chilean and Argentine Patagonia, independently. The native grey fox (Pseudalopex griseus) was introduced from Chilean to Argentine Tierra del Fuego. Few spread rates are available: the lowest are 10 km/yr and correspond to American beaver and American mink; intermediate rates are observed in muskrat and rather questionably, in grey fox; the highest rates (10-20 km/yr) are found among European hare and European rabbit. Because of their frequent migration, it is difficult to estimate the natural spread rate for wild boar and red deer. Not all mammal invasions in Chilean and Argentine Patagonia have been methodical advances of species; some involve an overlap of invasion fronts, with advances and retreats, and perhaps with re-invasions to different areas of either country. Because national policies with regard to introduced species may differ between countries sharing porous borders, it seems advisable to coordinate such policies in order to prevent the entry of unwelcome invaders.

Kafcas, E. N. 1987.
Census and exploitation of a discrete beaver population in Michigan.
1987:89. Central Michigan University.

Purpose was to develop a census technique, while evaluating beaver exploitation rates under 1979 and 1980 trapping regulations. The census technique related year-to-year changes in colony population size with numbers of colonies present, using the food cache method. Data concerning reproduction, population dynamics,. age, weight and movements, and habitat condition were collected to assess effects of trapping regulations.

Knudsen, G. J. 1955.
Wisconsin fur research: Beaver movement studies.

Knudsen, G. J. and J. B. Hale. 1965.
Movements of transplanted beavers in Wisconsin.
Journal of Wildlife Management. 29:685-688.
From 1951 to 1957, 2,200 beavers (Castor canadensis) were livetrapped in north and central Wisconsin, ear-tagged, and moved to new release sites. Recaptures totaled 472. Mean movement distances of recaptured beavers transplanted to streams were more than twice as long as for

beavers transplanted to potholes and lakes. This relationship held true for both sexes. Landlocked waters are recommended as the best release sites for transplants.

Koenen, K., S. Destefano, C. Henner and T. Beroldi. 2005.
From the Field: Capturing beavers in box traps.
Wildlife Society Bulletin. 33:1153-1159.
The article presents a study which used box traps to capture aquatic species such as beavers for wildlife research studies. The demography and movements of beavers across a suburban-rural gradient was studied after they were captured. The box traps used for the study were constructed with metal frames and wire mesh and the dimensions ranged from 38 x 38 x 122 cm to 48 x 48 x 122 cm. The traps weighed 14.5 kg on an average. The traps were placed along the feeding trails, at waters edge, on dams, and in runways. The captured beavers were immobilized with an intramuscular injection of ketamine hydrochloride and acepromazine. The age and sex of the beavers were determined and they were marked with metal and plastic ear tags and a tail-mounted radio transmitter. With the use of box traps the capture rates for beavers improved from about 11% in 2001-2002 to 21% in 2003. The modifications that improved door-locking mechanisms and the increased experience with trap placement and setup helped improve the beaver capture rate.

Lancia, R. A. 1979.
Year-long activity patterns of radio-marked beaver (Castor canadensis).
161:5678. University of Massachusetts.

DISSERTATION (PH.D.) - UNIVERSITY OF MASSACHUSETTS. APPENDIX I - KETAMINE HYDROCHLORIDE AS AN IMMOBILANT AND ANAESTHETIC FOR BEAVER. J. WILDL. MANAGE. 92(3): 946-948. APPENDIX II - A TELEMETRY SYSTEM FOR CONTINUOUSLY RECORDING LODGE USE, NOCTURNAL AND SUBNIVEAN ACTIVITY OF BEAVER (CASTOR CANADENSIS)

Leege, T. A. and R. M. Williams. 1967.
Beaver productivity in Idaho.
Journal of Wildlife Management. 31:326-332. Idaho Fish and Game Department.

Data on the productivity of beavers (Castor canadensis), including sex and age ratios, litter size, and rate of pregnancy, were gathered from livetrapping and fur-trapping operations in 1953-56 and 1962-64. Standard methods were used for determining sex and age of both live beavers and carcasses. Uteri hardened and discolored by preservatives were cut longitudinally to expose breaks on the internal ridge of tissue which pointed out sites of placentation. Counts of placental scars and fetuses indicated average litter size to be 3.1 and 3.4, respectively. The percentage of yearling and older females with placental scars dropped from 46.2 in the mid-1950's to 32.3 in the 1960's in southeastern Idaho, possibly owing to increased disturbance of colonies from accelerated fur trapping. Males consistently outnumbered females in kit and yearling age-classes while females were more abundant among the adults. The sex ratio of 352 beavers examined was 113 males per 100 females. Twenty-one percent of these animals were kits, 23 percent yearlings, and 56 percent adults. A disturbed (trapped) beaver population had a lower percentage of kit and yearling beavers than did an undisturbed population (35 percent vs. 49 percent). A highly migratory population consisted of 38 percent late yearlings, supporting the belief that beavers leave their home colony when almost 2 years old.

Leege, T. A. 1964.
Beaver productivity and movements in southeastern Idaho.
52:

Leege, T. A. 1968.
Beavers on the move.
Idaho Wildlife Review. 20:14-16.
In 1962 and 1963, traps were set on national forest lands in Idaho to determine beaver movements. Of the 192 beavers caught and tagged, 87 were recaptured. The calculated moving distance for 19 migrants found at least one airline mile from their tagging sites averaged 5.6 miles.

Leege, T. A. 1968.
Natural movements of beavers in southeastern Idaho.
Journal of Wildlife Management. 32:973-976.

Libby, W. L. 1957.
Observations on beaver movements in Alaska.
Journal of Mammalogy. 38:
One beaver, tagged when 2 years old, traveled at least 150-200 mi. Of 121 others, 2 traveled at least 6 mi., 16 traveled more than 1 but less than 6 mi., 16 moved less than 1 mi., and 87 were recovered in vicinity of tagging.

Lyons, P. J. 1979.
Effects of induced sterility on reproduction and dispersal patterns in beaver colonies.
123. University of Massachusetts.

McKinstry, M. C. and S. H. Anderson. 2002.
Survival, fates, and success of transplanted beavers, Castor canadensis, in Wyoming.
Canadian Field-Naturalist. 116:60-68 | 60.
Beaver (Castor canadensis) through their dam building activities, store water, trap sediment, subirrigate vegetation, and subsequently improve habitat for fish, wildlife, and livestock. Many landowners realize the benefits that Beaver can bring to a riparian area and are interested in using them to improve this habitat. From 1994 to 1999 we trapped and relocated 234 Beaver to 14 areas throughout Wyoming to improve riparian habitat and create natural wetlands. We attached radio transmitters to 114 Beaver and subsequently determined movements and mortality of released Beaver, and the overall success of our releases. Mortality and emigration (including transmitter failure) accounted for the loss of 30% and 51%, respectively, of telemetered Beaver within 6 months of release. Kaplan-Meier survival estimates were 0.49 (SE=0.068) for 180 days and 0.433 (SE=0.084) for 360 days, and did not differ significantly between age classes. On average, 17 Beaver were transplanted to each release site, and at 11 locations, in an attempt to augment single Beaver that had become established and increase transplant success, we transplanted Beaver in two or more years. Success of an individual Beaver's relocation was

unrelated to any of the variables we tested, although 2-3.5 year-old Beaver had higher average success (measured in days of occupancy at the release site) than older animals. Animals <2 years old had 100% mortality and emigration losses within 6 months of release. High predation and mortality rates of our released Beaver may be due to habitat (our streams were shallow with no ponds and provided little protection) and extensive predator communities. We established Beaver at 13/14 of our release sites and they eventually reproduced. Our results show that Beaver can be relocated successfully but losses from mortality and emigration need to be considered and planned for.

Muller-Schwarze, D., M. Dehnhard and H. Hofer. 2002.
Quantification of scent signals and identification of active compounds based on biotests.
Advances in Ethology. 190.
[unedited] Many analyses start with measuring what is easiest to measure: the largest "peaks" representing the compounds present in the highest concentrations, without accompanying behavior studies. While the measured compounds may correlated with species, sex, maturity, social status or health in pattern analysis, they are not necessarily the compounds that modulate behavior. Often very minor compounds are the critical ones. In the next level of analysis, one tries to relate presence or absence, or concentrations of specific compounds to demonstrated status of the studied animals, such as dominance, without behavior experiments. Experimental manipulation of endocrine status, for instance, leading to loss or enhancement of certain compounds, gives us further clues. Up to here we do not know what triggers or modulates behavior or development. The correlating compounds may be mere precursors or fixatives, for active ones. The real test is "response-guided fractionation", a step-by-step interaction between chemists and behaviourists. It can become rather complex, if several active compounds act together, and occur in different fractions. Mammals do not necessarily rely on very specific compounds and amounts. In contrast to many insects, the behavior can be affected in the same way by a wide range of concentrations, and also by different compounds, representing adaptive redundancy. Such flexibility may be useful under varying environmental conditions, such as different supplies of diet-derived compounds. Castoreum in beavers appears to be such an example of variable composition leading to the same territorial behaviors. On the other hand, to use secretions for taxonomic purposes, one expects a high degree of (genetically anchored) constancy. The anal secretion of beavers appears to belong into this category.

Patenaude, F. 1984.
The ontogeny of behaviour of free-living beavers (*Castor canadensis*).

Payne, N. F. 1989.
Population dynamics and harvest response of beaver.
Proceedings of the Fourth Eastern Wildlife Damage Control Conference. 127:127-132.
The author discusses beaver population control and various aspects of beaver life history. Habitat use, territoriality, colony size, dispersal, reproduction, mortality, and population response to harvesting are investigated in this paper.

Robel, R. J., L. B. Fox and K. E. Kemp. 1993.
Relationship between habitat suitability index values and ground counts of beaver colonies in Kansas.

Wildlife Society Bulletin. 21:415-421 | 415.

Rothmeyer, S. W., M. C. McKinstry and S. H. Anderson. 2002.
Tail attachment of modified ear-tag radio transmitters on beavers.
Wildlife Society Bulletin. 30:425-429 | 425.
Beavers (Castor canadensis) have fusiform bodies, tapered necks, and use aquatic habitats that have many entanglement hazards, making them inappropriate candidates for external radio transmitters. Surgically implanted transmitters are the primary means of monitoring beaver movements, but they have several drawbacks including general trauma, anesthesia, sterility, expense, and increased logistical problems, especially with field surgeries. From 1994 to 1999, we relocated over 234 beavers (121 with transmitters) as part of a project to improve riparian habitat and create wetlands at 14 locations throughout Wyoming. We needed a method to radio-tag beavers that was quick, inexpensive, easily taught, and practical under remote and primitive conditions. We developed a technique to quickly attach external transmitters to a beaver's tail with no recovery period. We found that modified ear-tag transmitters were more effective than collars placed at the base of the tail; tail collars slipped free on 75% of the animals we tagged (5 of 8 attachments) and presented entanglement hazards (1 of 8 attachments). The modified ear-tag technique was also less traumatic to beavers than surgical implants; we lost 7 of 58 (12%) of our surgically implanted beavers to anesthesia or surgery-related causes. Additionally, modified ear-tag transmitters could be used on animals too small to accommodate tail collars or implants. Fastening modified ear-tag transmitters to the tail was an efficient, quick, and easy technique and presented lower health risks than other methods of transmittering beavers.

Schulte, B. A. 1993.
Chemical communication and ecology of the North American beaver (Castor canadensis).
College of Environmental Science and Forestry. State University of New York.

Schulte, B. A. 1998.
Scent marking and responses to male castor fluid by beavers.
Journal of Mammalogy. 79:191-203 | 191.
Beavers construct mud mounds marked with urine-based castoreum. The author studied predictions of a territorial hypothesis for scent marking based on the ability of beavers to detect and discriminate scents. They also investigated whether signs of intrusion by other animals caused the beaver to build mounds. lgh.

Smith, D. W. and R. O. Peterson. 1991.
Behavior of beaver in lakes with varying water levels in Northern Minnesota.
Environmental Management. 15:395-401.
The effects of winter water drawdowns (2.3 meters) on beavers were studied in Voyageurs National Park, Minnesota, USA. The study was designed to sample areas within the park that differed in water drawdown regime. Lodges were counted and beavers were live-trapped and radio-implanted to study behavior, movements, and mortality. Active beaver lodge density, determined by aerial survey in 1984 and 1986, was greatest along the shoreline of the drawdown reservoir. In winter, beavers living on the drawdown reservoir spent less time inside their lodges, foraged more above ice, and were unable to fully use stored food, when compared to beavers from stable water environments. Only one case of starvation was documented in the drawdown

reservoir. Beavers in reservoirs that were drawn down survived winter in poorer condition than did beavers living where water levels remained high. In spite of an increasing population and lack of a widespread mortality, winter water drawbacks did not alter beaver behavior. To reduce these impacts, total annual water fluctuation should not exceed 1.5 meters and winter drawdown should not exceed 0.7 meters.

Sun, L., D. M□ller-Schwarze, B. A. Schulte and M.-S. D. 2000.
Dispersal pattern and effective population size of the beaver.
Canadian Journal of Zoology. 78:393-398.
The dispersal pattern of the beaver (Castor canadensis) was studied by intensive livetrapping, tagging, and observation in Allegany State Park and its vicinity in New York from 1984 to 1996. The majority (74%) of dispersing beavers (n = 46) initiated dispersal in a downstream direction after spring ice-out. Females dispersed significantly farther away from their natal colonies than males (10.15 ± 2.42 (SE) km vs. 3.49 ± 0.86 km). Movements to neighboring sites were common (16 of 46 dispersers), indicating that beavers, especially males, may prefer to disperse to the nearest available sites. Most (64%) natal dispersers were two-year-olds. Three-year-olds also constituted a considerable proportion (21%) of the dispersers, but one-year-old dispersers were relatively rare (14%). Many adults underwent secondary dispersal after successful natal dispersal in the study area. Male secondary dispersers were more inclined to take over neighboring sites than were male natal dispersers (10 of 13 vs. 3 of 13). The effective population size in a 250-km~2~ area was estimated to be 161-228 individuals by the areal method and 267-378 individuals by the 85th percentile method.

Svendsen, G. E. 1980.
Patterns of scent-mounding in a population of beaver (*Castor canadensis*).
Journal of Chemical Ecology. 6:133-148.

Townsend, J. E. 1952.
A study in beaver ecology in western Montana with special reference to movements.
Montana State University.

See J. Mamm. 34(4): 459-479. Nov. 1953.

Townsend, J. E. 1953.
Beaver ecology in western Montana with special reference to movements.
Journal of Mammalogy. 34:459-479.
Based on 3 summers of work on a 160-acre area. Live-trapping and observation were used. Marking by web punching was not found suitable for large scale studies, marks becoming obscure. Weights and measurements are correlated with age classes. Activities and foods are discussed. Movements of individuals and changes in colony composition are treated at length. Both yearlings and 2-year-olds may travel. The latter appear to become settled in late summer. Adult males travel considerably in summer, much more than breeding females. Data suggest that adult males do not remain with breeding females in spring and early summer. Population pressure seems to determine colony limits. Composition of colonies varies with season and year.

Van Deelen, T. R. 1991.

Dispersal patterns of juvenile beavers in western Montana.
University of Montana.

Van Deelen, T. R. and D. H. Pletscher. 1996.
Dispersal characteristics of two-year-old beavers, Castor canadensis, in western Montana.
Canadian Field-Naturalist. 110:318-321.

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

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. 111:217-222.
The author studied differences in home range sizes in beavers living in ponds, lakes, and rivers. Beavers living in rivers had larger home ranges than those living in ponds, but no differences were evident between those living in rivers and in lakes or between those in ponds and in lakes. When non-family beavers were excluded from the analysis no differences in home range size were found among the habitats. Activity in the core areas did not differ among habitats in summer, but in fall, core area activity was greater in lakes than in rivers regardless of whether non-family beavers were included. lgh.

Wheatley, M. 1997.
Beaver, Castor canadensis, home range size and patterns of use in the taiga of southeastern Manitoba: II. Sex, age, and family status.
Canadian Field-Naturalist. 111:211-216.
The author studied the differences in home range size and patterns of use in relation to age, sex, and family status for beaver living in family and non-family groups. Home ranges were larger for non-family groups than family groups during summer, but not in fall. Core areas were also larger for non-family groups during summer, but not in fall. Adult females in families had smaller home ranges than other family members in summer, but not in fall. Core area statistics did not vary among sex and age classes within family groups. lgh.

Wheatley, M. 1997.
Beaver, Castor canadensis, home range size and patterns of use in the taiga of southeastern Manitoba: I. Seasonal variation.
Canadian Field-Naturalist. 111:204-210.
According to a survey of seasonal variation of beaver home ranges from 1986 to 1992 in the taiga of southeastern Manitoba, summer home ranges were larger than fall home ranges, while both were larger than winter ranges. Beaver occupied core areas in summer and fall, but winter ranges consisted only of the area of the lodge with no core areas evident. lgh.

Woolf, A. and L. B. McNew Jr. 2005.
Dispersal and survival of juvenile beavers (Castor canadensis) in southern Illinois.
American Midland Naturalist. 154:217-228.

We used radiotelemetry to estimate natal dispersal patterns and survival rates of 13 yearling and 19 subadult beavers (Castor canadensis) at two geornorphologically different sites in southern Illinois. Overall, we observed a 55% dispersal rate for yearlings and a 73% dispersal rate for subadults. Normally, juveniles (yearlings + subacults) initiated dispersal around 16 February (range = 28 Jan-20 Mar.) and settled around 18 April, with juveniles remaining transient from late January through late June. Nine subadult beavers dispersed significantly earlier at one site (K = 25 Nov., range = 31 Oct.-16 Dec.), presumably due to intracolony strife brought on by management-induced autumn flooding of wetlands for waterfowl. Dispersal occurred earlier than documented in northern regions. Beavers dispersed farther from natal colonies with free-flowing water access ((x) over bar = 5.9 km) than those landlocked ((x) over bar = 1.7 km). Males moved more frequently and traveled greater distances per individual move than did females, but overall dispersal distances were similar between sexes. Dispersal distances of beavers with access to free-flowing water-ways generally were similar to other studies. Survival during dispersal was greater for beavers emigrating from lodges on the land-locked, less densely populated site (0.80), than for those dispersing in an area of higher population densities (0.43), but did not differ between dispersers and non-dispersers at either site.

Ecosystem function

Andersen, D. C. and D. J. Cooper. 2000.
Plant-herbivore-hydroperiod interactions: effects of native mammals on floodplain tree recruitment.
Ecological Applications. 10:1384-1399.
Floodplain plant-herbivore-hydroperiod interactions have received little attention despite their potential as determinants of floodplain structure and functioning. The authors used five types of exclosures to differentially exclude small-, medium-, and large-sized mammals from accessing Fremont cottonwood (Populus deltoides Marshall subsp. wizlizenii (Watson) Eckenwalder) seedlings and saplings growing naturally on four landform types at an alluvial reach on each of two rivers, the Green and Yampa, in Colorado and Utah. The two study reaches differed primarily as a result of flow regulation on the Green River, which began in 1962. Landforms were a rarely flooded portion of the alluvial plain, geomorphically active slow- and fast-water channel margin sites on the Yampa reach, and an aggrading side channel on the Green. Small-mammal live-trapping and observational data indicated that, with minor exceptions, the kinds of mammals eating cottonwood within each reach were identical. The authors monitored condition and fates of individual cottonwood plants from October 1993 through the 1997 growing season. Differences in survival and growth were noted both within and between reaches, and both due, to, and independent of, mammalian herbivory. Comparisons of cottonwood growth and survivorship among exclosures and between exclosures and controls indicated that a small mammal, Microtus montanus, reduced seedling and sapling survivorship at the Green River reach, but to a lesser extent (seedlings) or not at all (saplings) on the Yampa reach. In contrast, reductions in sapling height increment attributable to medium- and large-sized herbivores were detected only at the Yampa site. They suggest that these differences are a result of (1) flow regulation allowing Microtus populations to escape the mortality normally accompanying the large, snowmelt-driven spring flood, as well as regulation promoting a herbaceous understory favorable to voles, and (2) greater browsing pressure from overwintering deer and elk at the Yampa reach, unrelated to flow regulation. Within areas used by foraging beaver, the

probability of a sapling being cut by beaver was similar on the two reaches. This study suggests that changes in riparian plant-herbivore relationships due to shifts in river hydrology may be a common and important consequence of river regulation.

Bailey, J. K., J. A. Schweitzer, B. J. Rehill, R. L. Lindroth, G. D. Martinsen, T. G. Whitham and J. K. Biley. 2004.
Beavers as molecular geneticists: a genetic basis to the foraging of an ecosystem engineer.
Ecology. 85:603-608.
Ecological genetics is increasingly recognized as critical to understanding interactions among organisms and ecosystem processes. Using a common garden with pure and hybrid cottonwood trees of known genotype, two years of field surveys, and a cafeteria feeding experiment, we link introgression of Fremont genetic markers, condensed tannins (a genetically based plant trait), and foraging by beavers. These data support two major arguments. First, hybridization is an important mechanism for the transmission of ecologically functional traits. Second, links between a genetically based plant trait in a dominant riparian-forest tree species and the foraging behavior of beavers, an ecosystem engineer, emphasize that genetically based plant traits can directly and indirectly link population, community, and ecosystem processes.

Bailey, J. K. and T. G. Whitham. 2006.
Interactions between cottonwood and beavers positively affect sawfly abundance.
Ecological Entomology. 31:294-297.
1. Cottonwood (Populus spp.) are the dominant tree type in riparian forests of the western U.S.A. In these riparian forests, the beaver (Castor canadensis) is a major ecosystem engineer that commonly browses cottonwood, resulting in distinct changes to plant architecture. Here the hypothesis that beaver herbivory indirectly affects the distribution of a keystone leaf-galling sawfly through architectural changes in cottonwood was examined.2. It was found that: (a) beaver herbivory of cottonwood results in an increase in average shoot length over unbrowsed cottonwood; (b) sawfly galls were up to 7-14 times more abundant on browsed cottonwood than unbrowsed cottonwood; and (c) sawfly gall abundance was correlated positively with changes in shoot length after beaver herbivory. Together these data show that the individual and combined effects of cottonwood and beaver herbivory increase shoot length, positively affecting sawfly abundance.3. Because herbivores are a ubiquitous component of most ecosystems, we argue that the indirect effects of herbivory on plant quality, and subsequently other herbivores, may be as important as environmental variation.

Baker, B. W. 2003.
Beaver (Castor canadensis) in heavily browsed environments.
Lutra. 46:173-181.
Beaver (Castor canadensis) populations have declined or failed to recover in heavily browsed environments. I suggest that intense browsing by livestock or ungulates can disrupt beaver-willow (Salix spp.) mutualisms that likely evolved under relatively low herbivory in a more predator-rich environment, and that this interaction may explain beaver and willow declines. Field experiments in Rocky Mountain National Park, Colorado, USA, found the interaction of beaver and elk (Cervus elaphus) herbivory suppressed compensatory growth in willow. Intense elk browsing of simulated beaver-cut willow produced plants which were small and hedged with a high percentage of dead stems, whereas protected plants were large and highly branched with a

low percentage of dead stems. Evaluation of a winter food cache showed beaver had selected woody stems with a lower percentage of leaders browsed by elk. A lack of willow stems suitable as winter beaver food may cause beaver populations to decline, creating a negative feedback mechanism for beaver and willow. In contrast, if browsing by livestock or ungulates can be controlled, and beaver can disperse from a nearby source population, then beaver may build dams in marginal habitat which will benefit willow and cause a positive riparian response that restores proper function to degraded habitat. In a shrub-steppe riparian ecosystem of northwestern Colorado, USA, rest from overgrazing of livestock released herbaceous vegetation initiating restoration of a beaver-willow community. Thus, competition from livestock or ungulates can cause beaver and willow to decline and can prevent their restoration in heavily browsed riparian environments, but beaver and willow populations can recover under proper grazing management.

Braeuer, I. 2002.
Economic valuation of ecosystem functions - the value of increased nitrogen retention in beaver modified streams.
Verhandlungen der fesellschaft fuer oekologie. 32:

Danell, K., T. Willebrand and L. Baskin. 1998.
Mammalian herbivores in the boreal forests: their numerical fluctuations and use by man.
Conservation Ecology. 2:1-20.
The authors present an account of the population fluctuations of mammalian herbivores occurring in the boreal forests of the Nearctic and Palaearctic and their interrelation with humans. The boreal forests support rich natural resources that have been used over centuries by mankind for survival. The mammalian species are the most important resource that have provided man with food and products of commercial importance like antlers and hides. Their impact on plant succession, and their role in increasing the wetland mosaic and altering the hydrology of important ecosystems is also significant. These mammalian herbivores exhibit fluctuating cycles that are evident on different trophic levels. There are three types of fluctuations. The first two groups contain species with regular fluctuations and the third group contains species with irregular fluctuations. Thus, a variation in population size that lacks stable resource-dependent equilibrium seems to be characteristic of population fluctuations of many large ungulates. This study indicated that forest management that reduces the structural and spatial diversity at the stand, as well as at the landscape, level affects boreal forest habitats. Management of silvicultural that supports same age trees improves conditions for species favoring young forest stands, but it makes the situation worse for species that depend on old-growth forests. Another aim of management is the attempt at successful increase of population sizes of mammals. However, this population increase might go out of control leading to destabilization and destruction. Therefore it can be concluded that management of boreal forest ecosystems should be both substantial and long lasting.

D'Eon, R. G. 1995.
Beaver handbook: A guide to understanding and coping with beaver activity.
Northeast Science & Technology, Ontario Ministry of Natural Resources.

Beavers are an important part of North American ecosystems, but can also cause problems such as road washouts and flooded timberland. This handbook is intended to help resource managers and field staff in northern Ontario address problems related to beaver activity. The information in the handbook was gathered from a survey of people with experience and knowledge of beaver problems. It includes a review of beaver biology and behavior, beaver management practices in Ontario, and beaver control measures that have been found effective in certain situations. These measures include various types of screens or grills for preventing beavers from blocking culverts and road crossings, beaver fences, and beaver pond levellers.

Dollar, T. 2002.
Leave it to beavers.
Wildlife Conservation. 105:28-35 | 28.
The author describes the role beavers play in maintaining the wetland ecosystem at San Pedro Riparian National Conservation Area in Arizona. Human activities like mining, grazing, and woodcutting in the late 19th century and urbanization and water pumping recently, led to severe degradation of this ecosystem. The San Pedro River over the years was severely diminished by human activities and the beavers that were a natural part of the ecosystem were wiped out by poaching. In 1988, in a series of land exchanges the 58,000 acre San Pedro Riparian National Conservation Area, encompassing a 40 mile stretch of the river, was established under the management of the U.S. Bureau of Land Management (BLM). Since March 1999, 10 beavers were trapped from several areas, fitted with radio-transmitters, and reintroduced to the San Pedro NCA where they immediately formed pairs and started their damming activities. Biologists hope that in the coming years around 20 beaver colonies will develop along the river. Wildlife biologist Mark Fredlake, who monitors the activities of the reintroduced beavers, observed that after a wildfire and devastating floods that damaged four of the five beaver dens, the beavers survived and got back to building dams. Beaver dams help restore the ecosystem and the largest of the dams, 75 feet wide and around 3 m high, had backed water for a quarter-mile upstream. Areas that had dried up over the years started to re-grow wetland vegetation. With protection, the habitat has improved and around 220 species of birds are reported to breed here and over 450 bird, 47 amphibian and reptile, and 100 butterfly species have been observed. However, urban sprawl and unchecked water pumping is draining the river and all efforts of the beavers will come to naught unless these activities are checked.

Hadidian, J. 2003.
Managing conflicts with beaver in the United States: an animal welfare perspective.
Lutra. 46:217-222.
As had happened earlier in Europe, the American beaver (Castor canadensis) was almost completely extirpated from its historic range because of human exploitation. Anywhere from 50 to 400 million beaver may have occurred throughout North America prior to the arrival of Europeans. Today, the population in the United States has recovered from unknown historic lows to a point where conflicts with humans have notably increased. The standard approach to resolving human-beaver conflicts has been to kill beaver and destroy their structures. From both an environmental as well as animal welfare perspective this approach is regarded as short-sighted. This paper addresses the issue of humane and environmentally responsible beaver conflict management, and identifies alternatives that control the problems beaver cause without necessitating their removal. It also addresses the benefits created by the presence of beaver in

even highly urbanized ecosystems and details the strategy of one animal protection organization, the Humane Society of the United States, to educate the public about the beneficial role these animals can play.

Harwood, G. D. 1992.
A reappraisal of beavers as providers of ecosystem services.
Journal of the Colorado-Wyoming Academy of Sciences. 24:39.

Hebblewhite, M., C. A. White, C. G. Nietvelt, J. A. McKenzie, T. E. Hurd, J. M. Fryxell, S. E. Bayley and P. C. Paquet. 2005.
Human activity mediates a trophic cascade caused by wolves.
Ecology. 86:2135-2144.
Experimental evidence of trophic cascades initiated by large vertebrate predators is rare in terrestrial ecosystems. A serendipitous natural experiment provided an opportunity to test the trophic cascade hypothesis for wolves (Canis lupus) in Banff National Park, Canada. The first wolf pack recolonized the Bow Valley of Banff National Park in 1986. High human activity partially excluded wolves from one area of the Bow Valley (low-wolf area), whereas wolves made full use of an adjacent area (high-wolf area). We investigated the effects of differential wolf predation between these two areas on elk (Cervus elaphus) population density, adult female survival, and calf recruitment; aspen (Populus tremuloides) recruitment and browse intensity; willow (Salix spp.) production, browsing intensity, and net growth; beaver (Castor canadensis) density; and riparian songbird diversity, evenness, and abundance. We compared effects of recolonizing wolves on these response variables using the log response ratio between the low-wolf and high-wolf treatments. Elk population density diverged over time in the two treatments, such that elk were an order of magnitude more numerous in the low-wolf area compared to the high-wolf area at the end of the study. Annual survival of adult female elk was 62% in the high-wolf area vs. 89% in the low-wolf area. Annual recruitment of calves was 15% in the high-wolf area vs. 27% without wolves. Wolf exclusion decreased aspen recruitment, willow production, and increased willow and aspen browsing intensity. Beaver lodge density was negatively correlated to elk density, and elk herbivory had an indirect negative effect on riparian songbird diversity and abundance. These alternating patterns across trophic levels support the wolf-caused trophic cascade hypothesis. Human activity strongly mediated these cascade effects, through a depressing effect on habitat use by wolves. Thus, conservation strategies based on the trophic importance of large carnivores have increased support in terrestrial ecosystems.

Hood, G. A., S. E. Bayley and W. Olson. 2007.
Effects of prescribed fire on habitat of beaver (Castor canadensis) in Elk Island National Park, Canada.
Forest Ecology and Management. 239:200-209.
Fire, flooding, herbivory, and the effects of climate are all topical issues for today's land managers. Effective resource management requires a balance among these processes, which in turn, requires a better understanding of their interactions. Beaver (Castor canadensis) are strong colonizers and have been successfully reintroduced to much of their former range. Prescribed fire has also been introduced in many areas as a management tool to restore ecological function. Resource managers have often assumed fire would also benefit non-target species like beaver; however, its effect on beaver has not been well studied. In this study, part of a broader project in

Elk Island National Park, Canada, we examine the effect of prescribed fire on beaver lodge occupancy in the context of high ungulate populations. Elk Island National Park has an active beaver population, high ungulate densities, and a well-established prescribed fire program. We examine whether frequency, size, and timing of bums influence beaver lodge occupancy and the establishment of new lodges. Since 1979, over 51% of the park (99.3 km2) has been burned with prescribed fire. By comparing lodge occupancy over a period prior to and after a series of prescribed bums, we analyzed beaver occupancy rates pre- and post-burn. Our results show that repeated burning dramatically decreases beaver lodge occupancy, and that even after one bum the number of active colonies declines and does not recover to pre-fire populations. Especially when combined with drought and herbivory, prescribed fire does not improve beaver habitat. [copyright] 2006 Elsevier B.V. All rights reserved.

Hughes, P. and J. L. Dooley. 2006.
Beaver (castor canadensis) herbivory effects on an anthropogenically altered landscape.
The Ohio Journal of Science. 106:A-17.
[unedited] Beaver (Castor canadensis) have been referred to as ecosystem engineers, meaning that they greatly alter their environment. Beaver are able to affect species diversity and richness through their harvesting of woody plants. The goal of this study is to access the heavily altered landscape of the Wilds (in Muskingum county, Ohio). Prior to the establishment of the Wilds in the 1990s, this ecosystem was drastically altered by strip mining. Vegetation transects were established at sites currently used by beaver as well as at abandoned beaver sites. Tree species diversity was found to be low, and highly dominated by Autumn Olive and Sweetgum. Variables recorded were plant species composition as well as recruitment data in each of four subplots for nine transects across three sites. Descriptive statical analysis will include comparisons of response variables as a function of distance from water. Comparisons of currently active with abandoned areas should provide insights as a longer-term impacts of beaver foraging. Results from this study may provide important insights to develop a beaver management plan for the wilds.

Jakes, A. F., J. W. Snodgrass and J. Burger. 2007.
Castor canadensis (Beaver) Impoundment Associated with Geomorphology of Southeastern Streams.
Southeastern Naturalist. 6:271-282.
We used a geographic information system (GIS) and logistic regression to investigate relationships between geomorphology and Castor canadensis (North American beaver) impoundment of lower-order, blackwater streams of a southeastern landscape. Using GIS, we divided streams into 632 500-m reaches and measured a set of geomorphic variables for each reach. Beavers were most likely to impound stream reaches crossed by roads with a gradient of ? 0.6 to 1.2% and watershed sizes of ? 2500 ha; reaches with watershed sizes < ? 500 ha or > 5000 ha were almost completely avoided. Gradient and road crossings contributed little to discrimination among impounded and unimpounded reaches, suggesting these variables had relatively small influences on beaver impoundment when compared to stream size. Our results indicate that GIS and geomorphic variables can be used to model the impoundment of streams over larger areas (e.g., the proportion of third-order watersheds impounded), but are less accurate at predicting the impoundment of individual reaches. However, the temporal dynamics of

impoundment creation and abandonment will need to be incorporated into region-specific models before they can be used in ecosystem integrity assessment. (Author)

Johnston, C. A. and R. J. Naiman. 1990.
Aquatic patch creation in relation to beaver population trends.
Ecology. 71:1617-1621.

Lizarralde, M., J. Escobar and G. Deferrari. 2004.
Invader species in Argentina: A review about the beaver (Castor canadensis) population situation on Tierra del Fuego ecosystem.
Interciencia. 29:352-356, 403.
Beavers (Castor canadensis) were introduced at Isla Grande, Terra del Fuego, Argentina, in 1946. Suitable feeding and lodging sites, coupled with lack of natural predators or competitors favored rapid population growth and range expansion. This paper shows the current population status and landscape modifications induced by beavers in these southern ecosystems. Beavers are now found in all streams in the Andean and extra-Andean areas, and in nearly all aquatic habitats on Isla Grande as well as other Chilean islands of tire Tierra del Fuego archipelago (70000km2). Areas with low gradient in small streams are more densely occupied than those in slope valleys. Densities are similar to those in the Northern Hemisphere. Extensively colonized habitats showed 0.7 active beaver colonies per km2. Based on their different beaver occupancy patterns and frequency of colony sites, four land capability classes (A, B, C and D) were established to use in planning and resource management. The highest densities were found in classes C and D (4.7 and 5.6 colony sites per km2) indicating that both these areas had the greatest potential,for beaver production. Beaver-altered sites had higher levels of organic and inorganic N, suggesting that seasonal hydrological changes could be affecting nitrification and denitrification, also resulting in accumulated organic C and P in the stream channel. Beaver ponds may be considered sources of essential nutrients (P and N) and C. Chromosome analysis showed no differences with the North American karyotype. Genetic structure and variability of the beaver population are analyzed.

Longcore, T., C. Rich, D. Muller-Schwarze and D. Mueller-Schwarze. 2007.
Management by Assertion: Beavers and Songbirds at Lake Skinner (Riverside County, California).
Environmental Management. 39:460-471 | 460-71.
Management of ecological reserve lands should rely on the best available science to achieve the goal of biodiversity conservation. "Adaptive Resource Management" is the current template to ensure that management decisions are reasoned and that decisions increase understanding of the system being managed. In systems with little human disturbance, certain management decisions are clear; steps to protect native species usually include the removal of invasive species. In highly modified systems, however, appropriate management steps to conserve biodiversity are not as readily evident. Managers must, more than ever, rely upon the development and testing of hypotheses to make rational management decisions. We present a case study of modern reserve management wherein beavers (Castor canadensis) were suspected of destroying habitat for endangered songbirds (least Bell's vireo, Vireo bellii pusillus, and southwestern willow flycatcher, Empidonax traillii extimus) and for promoting the invasion of an exotic plant (tamarisk, Tamarix spp.) at an artificial reservoir in southern California. This case study

documents the consequences of failing to follow the process of Adaptive Resource Management. Managers made decisions that were unsupported by the scientific literature, and actions taken were likely counterproductive. The opportunity to increase knowledge of the ecosystem was lost. Uninformed management decisions, essentially "management by assertion," undermine the long-term prospects for biodiversity conservation. (Author)

MacCracken, J. G. and A. D. Lebovitz. 2005.
Selection of in-stream wood structures by beaver in the Bear River, southwest Washington.
Northwestern Naturalist. 86:49-58.
[unedited] Many habitat restoration projects for Pacific salmon (Oncorhynchus spp.) have placed wood structures in streams. We observed beaver (Castor canadensis) consistently using three wood structures placed in the Bear River as foundations for dams, which provided pool habitat for juvenile salmon. Determining why beaver used some structures and not others could help to increase the efficacy of wood placement through use by beaver. We conducted an exploratory study using model selection procedures based on Akaike's information criteria to assess the hypothesis that there were characteristics of the wood structures and their immediate environment that influenced use by beaver. A literature review and field observations were used to develop seven logistic regression models and the parameters of those models were estimated with data from 55 in-stream wood structures. One model had overwhelming support (Akaike weight = 0.9801) as the best in the set of seven examined. Variables in that model described both in-stream characteristics (channel confinement; and distance to log jams, deep pools, and beaver bank dens) and riparian conditions (floodplain width and hillside slope). Structures used by beaver were in unconfined channels, farther from other logjams, closer to deep pools and bank dens, in wider floodplains, and with less steep hillsides. The logistic regression model is a resource selection probability function that may be useful in designing wood placement projects if restoration ecologists and managers wish to enlist the services of beaver.

McCollum, R. C. 1992.
Comparative use of lower, headwater, and beaver-impacted floodplains by swamp rabbits.
59:Auburn University.

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.
On Beaver Creek (north shore Gulf of St. Lawrence, Quebec, Canada) in the 1983 ice-free season, standing stocks of coarse particulate organic matter (> 1 mm) were 2-5 times greater ($p<0.05$) in beaver-impounded sites than in riffle sites in spring and summer. Fine (212 micrometer-1 mm) and very fine (0.5 micrometer-212 micrometer) particulate organic matter were 3-10 times greater ($p<0.05$) in impounded sites in all seasons. Chlorophyll a standing stocks did not differ statistically among sites. Total density and biomass of invertebrates in impoundments were 2-5 times greater ($p<0.05$) than riffle sites in spring and summer, but statistically similar in autumn. Generic diversity (H') was greater ($p<0.05$) in unaltered sites in autumn. Non-impounded sites were dominated by Simuliidae, Tanytarsini chironomids, scraping mayflies, and net-spinning caddisflies, whereas impounded sites were characterized by Tanypodinae and Chironomini chironomids, predacious odonates, Tubificidae, and filtering

pelycopods. The present results suggest that paradigms currently applied to lotic ecosystems need to be reevaluated to incorporate the influence of beaver upon invertebrate communities.

McKinstry, M. C. and S. H. Anderson. 2003.
Survival, fates, and success of transplanted beavers (Castor canadensis) in Wyoming.
Journal of Wildlife Rehabilitation. 26:17-23.
[unedited] Beaver (Castor canadensis), through their dam building activities, alter riparian-stream ecosystems, and many landowners recognize these benefits. From 1994-1999, we trapped and relocated 234 beaver to 14 areas throughout Wyoming to improve riparian habitat and create natural wetlands. Radio transmitters were attached to 114 beaver. Mortality and emigration (included transmitter failure) accounted for the loss of 30% and 51%, respectively, of telemetered beaver within six months of release. On average, 17 beaver were transplanted to each release site; at 11 locations, in an attempt to augment single beaver that had become established and increase transplant success, we transplanted beaver in two or more years. Success of an individual beaver's relocation was unrelated to any of the variables tested. High predation and mortality rates of released beaver may be due to habitat and extensive predator communities. Beaver were established at 13/14 of our release sites and they eventually reproduced.

Mitsch, W. J., J. W. Day and J. W. Day Jr. 2004.
Thinking big with whole-ecosystem studies and ecosystem restoration - a legacy of H.T. Odum.
Ecological Modelling. 178:133-155.
Whole-ecosystem studies are in situ ecological studies and experiments of such a spatial and temporal scale as to include most if not all processes of the ecosystem. Principles of self-organization and self-design are key to whole-ecological function and often do not occur as vibrantly or conclusively at smaller scale experiments. Ecological feedback caused by organisms (e.g., beavers, plants that manage hydrology, ecosystem engineers, top-down control), pulses caused by events such as fire and floods, and emergent ecosystem properties caused by human wastes, recycling, and hydrologic modification are difficult if not impossible to be properly studied in small-scale experiments. Large-scale whole-ecosystem studies were pioneered in the 1960s and 1970s by H.T. Odum and colleagues with large drop nets in Texas coastal bays, rain forests enclosures in Puerto Rico, created coastal ponds in North Carolina, and sewage application to cypress swamps in Florida. The study in Florida investigated effects of wastewater additions to wetland function in cypress domes but unexpected fire in the experimental area led to adaptive research and the study of fire in field research and models. More recently we have been engaged in whole-ecosystem experiments, partially inspired by the work of Odum, at created wetlands in northeastern Illinois to investigate effects of water turnover on ecosystem function and in Ohio to provide insight on the long-range large-scale effects of hydrology and macrophyte planting on ecosystem function. We have also carried out major ecosystem-scale studies in coastal Louisiana, investigating the value of these ecological systems in treating wastewater and restoring lost landscape in coastal Louisiana. These studies in the Midwest and Mississippi delta form the basis of determining design standards on creating and restoring wetlands in the Mississippi River Basin to reduce the Gulf of Mexico hypoxia and regain many lost ecosystem functions over a large part of North America. [copyright] 2004 Elsevier B.V. All rights reserved.

Naiman, R. J. and J. M. Melillo. 1984.
Nitrogen budget of a subarctic stream altered by beaver (Castor canadensis).
Oecologia. 62:150-155.
Beaver (Castor canadensis) affect the structure and dynamics of stream ecosystems by transferring organic matter from the terrestrial to the aquatic system and by building dams. To quantify their influence, measured rates of nitrogen dynamics were used to construct a nitrogen budget for a section of a second order stream (Beaver Creek) in eastern Quebec and a beaver dam in that stream. The budget demonstrates the importance of sediment accumulations and an expanded wetted area to the annual nitrogen economy and to pathways of nitrogen cycling. Major changes after impoundment (per unit area) include a reduction in allochthonous nitrogen and an increase in nitrogen fixation by sediment microbes. In riffles, 83.3% of the annual nitrogen inputs (7.2 g N/sq m) are accounted for by direct allochthonous inputs (56.9%) or as lateral inputs form the forest floor (26.4%). In the beaver pond, most of the annual input (7.7 g N/sq m) is accounted for by nitrogen fixation associated with accumulated sediment (66.2%); direct allochthonous inputs have been reduced to 22.1% and lateral inputs to 1.3% of the budget. Precipitation contributes 9.1%, but throughfall and nitrogen fixation associated with wood are negligible. The turnover time for nitrogen is a slow 72.4 yr. Overall, the beaver-modified section accumulated about 1000 times more nitrogen than before alteration. The ecosystem implications of beaver activity suggest that current concepts of patterns and processes in running waters require modification.

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.
The effects of beaver activity were examined on several major ecosystem components and processes in boreal forest drainage networks in Quebec. The density of dams on the small streams averaged 10.6 dams/km; the streams retain up to 6,500 cu m of sediment per dam, and the wetted surface area of the channel is increased up to several hundred-fold. Beaver are also active in larger order streams, but their effects are most noticeable along riverbanks and in floodplains. Beaver ponds are important sites for organic matter processing; the stream metabolism index, a measure of ecosystem efficiency for the utilization or storage of organic inputs, is 1.63 for a pond on 2nd order Beaver Creek compared to 0.30 for the riffle upstream from it; the turnover length for particulate carbon is 1.2 km for the pond compared to 8.0 km for the riffle. Beaver-induced alterations to the structure and function of streams suggest that removal of beaver prior to 1900 had substantial effects on the dynamics of lotic ecosystems. It is suggested that current concepts of the organization and diversity of unaltered stream ecosystems in North America should recognize the keystone role of beaver, as drainage networks with beaver are substantially different in their biogeochemical economies than those without beaver.

Nienhuis, P. H., J. P. Bakker, A. P. Grootjans, R. D. Gulati and V. N. De Jonge. 2002.
The state of the art of aquatic and semi-aquatic ecological restoration projects in the Netherlands.
Hydrobiologia: the international journal on limnology and marine sciences. 478:219-233.
The Netherlands are a small, low-lying delta in W. Europe (42 000 km2; 50[degree]-54[degree] N; 3[degree]-8[degree] E), mainly consisting of alluvial deposits from the North Sea and from the large rivers Rhine and Meuse. The country was "created by man". The conversion of natural aquatic and terrestrial ecosystems into drained agricultural land was a major cultural operation

over the past 1000 years. Roughly 55% of the country"s surface area is still agricultural land. Some decades ago, The Netherlands" landscape was characterised by an armoured coastline and bridled estuaries, a drastically reduced area of saline and freshwater marshes, fully regulated rivers and streams, and numerous artificial lakes. The aquatic ecosystems beyond the influence of the large rivers, the Pleistocene raised bogs and moor lands, have almost been completely annihilated in the past. Acidification and eutrophication led to the deterioration of the remaining softwater lake vegetation. Last but not least, an artificial drainage system was constructed, leading to an unnatural water table all over the country, high in summer, low in winter. Only very recently, some 25 years ago, the tide has been turned and ecological rehabilitation and restoration of disturbed ecosystems are in full swing now, enhanced by the European Union policy to set aside agricultural land in the Netherlands in favour of the development of "nature". The state of the art of aquatic and semi-aquatic ecological restoration projects in the Netherlands is given. Starting from the conceptual basis of restoration ecology, the successes and failures of hundreds of restoration projects are given. Numerous successful projects are mentioned. In general, ecological restoration endeavours are greatly benefiting from progressive experience in the course of the years. Failures mainly occur by insufficient application of physical, chemical or ecological principles. The spontaneous colonisation by plants and animals, following habitat reconstruction, is preferred. But sometimes the re-introduction of keystone species (e.g. eelgrass; salmon; beaver) is necessary in case the potential habitats are isolated or fragmented, or when a seed bank is lacking, thus not allowing viable populations to develop. Re-introduction of traditional management techniques (e.g. mowing without fertilisation; low intensity grazing) is important to rehabilitate the semi-natural and cultural landscapes, so characteristic for the Netherlands. For aquatic ecosystems proper (estuaries, rivers, streams, larger lakes) the rule of thumb is that re-establishment of the abiotic habitat conditions is a pre-requisite for the return of the target species. This implies rehabilitation of former hydrological end geomorphological conditions, and an increase in spatial heterogeneity. The "bottom-up" technique of lake restoration, viz. reduction in nutrient loadings, and removal of nutrient-rich organic sediment, is the preferred strategy. The "top-down" approach of curing eutrophicated ecosystems, that is drastic reduction of fish stock, mainly bream, and introduction of carnivorous fish, may be considered as complementary. For semi-aquatic ecosystems (river-fed and rain-fed peat moors, brook valleys, coastal dune slacks) it also counts that the abiotic constraints should be lifted, but here the species-oriented conservation strategy, the enhancement of the recovery of characteristic plant and animal species, is mainly followed. An important pre-requisite for the rehabilitation of the original natural or semi-natural vegetation is the presence of viable seed bank. Restoration of salt-marsh vegetation has to deal with a short-lived persistent seed bank, which means that transport of seeds by water currents is important. Isolated softwater ecosystems may rely on the long-lived seeds of the aquatic macrophytes. The paper ends with some notes on the predictability of the outcome of ecological restoration measures and the societal position of restoration ecology as a science. Scientists hold different views on the predictability of restoration measures. A fact is that the predictability of ecosystem development increases, with increasing knowledge of the underlying environmental processes.

Parker, J. D., C. C. Caudill and M. E. Hay. 2007.
Beaver herbivory on aquatic plants.
Oecologia. 151:616-625.

Herbivores have strong impacts on marine and terrestrial plant communities, but their impact is less well studied in benthic freshwater systems. For example, North American beavers (Castor canadensis) eat both woody and non-woody plants and focus almost exclusively on the latter in summer months, yet their impacts on non-woody plants are generally attributed to ecosystem engineering rather than herbivory. Here, we excluded beavers from areas of two beaver wetlands for over 2 years and demonstrated that beaver herbivory reduced aquatic plant biomass by 60%, plant litter by 75%, and dramatically shifted plant species composition. The perennial forb lizard's tail (Saururus cernutts) comprised less than 5% of plant biomass in areas open to beaver grazing but greater than 50% of plant biomass in beaver exclusions. This shift was likely due to direct herbivory, as beavers preferentially consumed lizard's tail over other plants in a field feeding assay. Beaver herbivory also reduced the abundance of the invasive aquatic plant Myriophyllum aquaticum by nearly 90%, consistent with recent evidence that native generalist herbivores provide biotic resistance against exotic plant invasions. Beaver herbivory also had indirect effects on plant interactions in this community. The palatable plant lizard's tail was 3 times more frequent and 10 times more abundant inside woolgrass (Scirpus cyperinus) tussocks than in spatially paired locations lacking tussocks. When the protective foliage of the woolgrass was removed without exclusion cages, beavers consumed nearly half of the lizard's tail leaves within 2 weeks. In contrast, leaf abundance increased by 73-93% in the treatments retaining woolgrass or protected by a cage. Thus, woolgrass tussocks were as effective as cages at excluding beaver foraging and provided lizard's tail plants an associational refuge from beaver herbivory. These results suggest that beaver herbivory has strong direct and indirect impacts on populations and communities of herbaceous aquatic plants and extends the consequences of beaver activities beyond ecosystem engineering.

Perkins, T. E. and M. V. Wilson. 2005.
The impacts of Phalaris arundinacea (reed canarygrass) invasion on wetland plant richness in the Oregon Coast Range, USA depend on beavers.
Biological Conservation. 124:291-295.
Invasive plants can threaten diversity and ecosystem function. We examined the relationship between the invasive Phalaris arundinacea (reed canarygrass) and species richness in beaver wetlands in Oregon, USA. Four basins (drainages) were chosen and three sites each of beaver impoundments, unimpounded areas and areas upstream of debris jams were randomly chosen in each basin for further study (n = 36). Analysis of covariance (ANCOVA) showed that the relationship between Phalaris and species richness differed significantly (p = 0.01) by site type. Dam sites (beaver impoundments) exhibited a strong inverse relationship between Phalaris and species richness (bD = -0.15), with one species lost for each 7% increase in Phalaris cover. In contrast, there was essentially no relationship between Phalaris cover and species richness in jam sites (debris jam impoundments formed by flooding; bJ = +0.01) and unimpounded sites (bU = -0.03). The cycle of beaver impoundment and abandonment both disrupts the native community and provides an ideal environment for Phalaris, which once established tends to exclude development of herbaceous communities and limits species richness. Because beaver wetlands are a dominant wetland type in the Coast Range, Phalaris invasion presents a real threat to landscape heterogeneity and ecosystem function in the region.

Pinay, G. and R. J. Naiman. 1991.

Short-Term Hydrologic Variations and Nitrogen Dynamics In Beaver Created Meadows.
Archiv fur Hydrobiologie. 123:187-205.
Beaver (Castor canadensis) alter the structure and dynamics of aquatic ecosystems through their dam building and feeding activities. The environmental heterogeneity in beaver-created meadows and wetlands was assessed over distance, soil depth, and time in Voyageurs National Park, Minnesota. The influence of aerobic and anaerobic boundaries on nitrogen availability in beaver-created meadows was also investigated. Short-term fluctuations of the hydrological regime enhanced sediment nitrogen dynamics and nitrogen availability for plant growth in an otherwise impoverished boreal environment. These natural water level changes sustained beaver wetlands and meadows in a loose equilibrium where imposed deviations of the environmental conditions tended to remain within fixed upper and lower bounds, but did not appear to have preferred values. Such dynamical equilibrium in beaver-created meadows for aerobic-anaerobic status at the scale of a few meters sustained the structure and dynamics of sedge and grass vegetative patches occurring between pond and upland zones at the landscape scale. Similar patterns of nitrate availability occurred in the active pond and in the abandoned pond. This similarity between active and abandoned ponds suggests that environmental processes occurring during stream impoundment have a long term effect on sediment structure and functioning, affecting the pond long after it was drained.

Ray, H. L., A. M. Ray and A. J. Rebertus. 2004.
Rapid establishment of fish in isolated peatland beaver ponds.
Wetlands. 24:399-405.
Previous research has demonstrated that beavers (Castor canadensis) dramatically alter fish habitat in streams by their dam-building activities. Although less well-known, beavers also flood closed peatlands by damming seepage rather than streamflow. Our study focuses on the establishment of fish communities in isolated beaver ponds created in small, ombrogenous peatlands lacking any open water prior to beaver occupation. We selected 16 ponds that ranged in age from 4 to 42 years and three unaltered peatlands to determine whether beaver promote the use of peatlands by fish and if the patterns of individual species were related to macrophyte density. Fish were present in ponds as young as four years old, and five of the six species of fish were present in ponds ltoreq 16 years old. Submersed macrophyte abundance explained 40% of the variation in fish diversity. Rapid colonization of fish in beaver-altered peatlands provides further evidence of how beavers increase the complexity of biological food webs in boreal regions. Moreover, this work provides an even greater understanding of the historical role of beavers as ecosystem engineers in peatland dominated landscapes.

Rosell, F., O. Bozs,r, P. Collen and H. Parker. 2005.
Ecological impact of beavers Castor fiber and Castor canadensis and their ability to modify ecosystems.
Mammal Review. 35:248-276.
1. The genus Castor comprises two species: the Eurasian beaver Castor fiber, and the North American beaver Castor canadensis. Both species suffered from overexploitation, but have seen a revival since the 1920s due to increased protection and reintroduction programmes. Increases in the populations and distributions of species that are able to modify ecosystems have generated much scientific interest. Here we review the available literature concerning the possible ecological impact of beaver species in the Old and New World.2. Beavers, being ecosystem

engineers, are among the few species besides humans that can significantly change the geomorphology, and consequently the hydrological characteristics and biotic properties of the landscape. In so doing, beavers increase heterogeneity, and habitat and species diversity at the landscape scale. Beaver foraging also has a considerable impact on the course of ecological succession, species composition and structure of plant communities, making them a good example of ecologically dominant species (e.g. keystone species).3. Nevertheless, the strength of beavers' impact varies from site to site, depending on the geographical location, relief and the impounded habitat type. Consequently, they may not be significant controlling agents of the ecosystem in all parts of their distribution, but have strong interactions only under certain circumstances. We suggest that beavers can create important management opportunities in the Holarctic, and this review will help land managers determine the likely outcome of beaver activity.

Sigourney, D. B., B. H. Letcher and R. A. Cunjak. 2006.
Influence of beaver activity on summer growth and condition of age-2 Atlantic salmon parr.
American Fisheries Society. Transactions. 135:1068-1075.
The activity of beavers Castor canadensis in freshwater environments can have considerable localized impacts on the physical and biological components of riparian ecosystems. By changing the habitat of a stream, beaver dams can cause spatial variation in growth opportunity that may have direct consequences for the growth of resident fish. In a small stream in eastern Canada, we studied the effects of an ephemeral beaver pond on the growth and maturity of age-2 Atlantic salmon Salmo salar parr tagged with passive integrated transponder tags. Water temperature remained relatively uniform throughout the study site. We found very little movement of recaptured fish in the study site. Fish that were recaptured in the beaver pond displayed faster summer growth rates in both length and mass than fish that were recaptured immediately above or below the pond. We also found that Parr in the pond maintained relatively high condition factors, whereas fish above and below the pond appeared to decrease in condition factor throughout the summer. In addition to growth, the maturation rates of age-2 males were higher above the dam than below. This study demonstrates the effect a beaver dam can have on individual growth rates. By influencing growth during sensitive periods, the beaver pond may also influence individual life history pathways. This information could be an important component in ecosystem models that predict the effect of beaver population dynamics on the growth of individual salmonids at the landscape scale.

Smith, M. E., C. T. Driscoll, B. J. Wyskowski, C. M. Brooks and C. C. Cosentini. 1991.
Modification of stream ecosystem structure and function by beaver (Castor canadensis) in the Adirondack Mountains, New York.
Canadian Journal of Zoology. 69:55-61.

Smith, M. E. and C. T. Driscoll. 1991.
Modification of stream ecosystem structure and function by beaver.
Georgia Journal of Science. 49:26-27.

Syphard, A. D. and M. W. Garcia. 2001.
Human- and beaver-induced wetland changes in the Chickahominy River watershed from 1953 to 1994.

Wetlands. 21:342-353.
Historically, anthropogenic activities have contributed to the direct loss of wetland area, mostly due to agriculture and urban land uses. Urbanization also indirectly impacts wetlands at a landscape scale through altered wetland hydrology and change in the spatial configuration of wetlands in a watershed. In addition, beaver (Castor canadensis) create and modify wetlands in a landscape. Because of recent increases in urbanization and rising beaver populations, a raster-based geographic information system (GIS) was used to analyze the combined effects of humans and beavers on wetland area and types in the Chickahominy River watershed from 1953 to 1994. Results of the study revealed that 29% of the land changed during the 41-year study period, and wetland conversion constituted seven percent of the total change. The major reason for wetland loss was the construction of two large water-supply reservoirs in the watershed, and most of the remaining wetland loss was due to urbanization. Wetland functions vary depending on wetland type, and the results of this study showed that 90% of the change in wetlands from 1953 to 1994 was a result of shifting between wetland types. Beaver-modified wetlands increased 274%, and beaver activity was responsible for 23% of the wetland change.

Voelker, B. W. and J. L. Dooley. 2006.
Impact on woody plants by the North American beaver (Castor Canadensis) at the wilds, Muskingum County, Ohio.
The Ohio Journal of Science. 105:A9-A10.
[unedited] The Wilds, a 4,050 hectare center for wildlife conservation, of southeastern Ohio has a history of intense surface-mining and provides an important opportunity for advancing restoration ecology. There is concern that the herbivory pressure of beaver (Castor canadensis) may negatively affect the restoration processes in the northern section of the property restored in 1973-1975. The canopy-opening foraging and selective feeding of beavers could influence the structure and diversity of woody plant communities. This study will assess the impact of beaver on an ecosystem recovering from surface-mining where the short-term and, more importantly, the long term effects of such beaver foraging on woody plants and therefore ecosystem recovery need to be quantitatively assessed. To study the influence of beaver on shoreline woody plants, one active and two recently abandoned beaver dam sites were chosen. Transects were established at all three sites and the following data recorded: woody plant diameter, species identity and cutting history by beaver. Analysis of these data will allow determination if browse selection affects the woody plant community at these sites and to assess the degree to which forest succession and recovery may be altered by beaver herbivory in terms of species richness, diversity and evenness.

Wohl, E. 2005.
Compromised Rivers: Understanding Historical Human Impacts on Rivers in the Context of Restoration.
Ecology & Society. 10:24-40 | 16.
A river that preserves a simplified and attractive form may nevertheless have lost function. Loss of function in these rivers can occur because hydrologic and geomorphic processes no longer create and maintain the habitat and natural disturbance regimes necessary for ecosystem integrity. Recognition of compromised river function is particularly important in the context of river restoration, in which the public perception of a river's condition often drives the decision to undertake restoration as well as the decision about what type of restoration should be attempted.

Determining the degree to which a river has been altered from its reference condition requires a knowledge of historical land use and the associated effects on rivers. Rivers of the Front Range of the Colorado Rocky Mountains in the United States are used to illustrate how historical land uses such as beaver trapping, placer mining, tie drives, flow regulation, and the construction of transportation corridors continue to affect contemporary river characteristics. Ignorance of regional land use and river history can lead to restoration that sets unrealistic goals because it is based on incorrect assumptions about a river's reference condition or about the influence of persistent land-use effects. (Author)

Wright, J. P., C. G. Jones and A. S. Flecker. 2002.
An ecosystem engineer, the beaver, increases species richness at the landscape scale.
Oecologia. 132:96-101.
Ecosystem engineering - the physical modification of habitats by organisms - has been proposed as an important mechanism for maintaining high species richness at the landscape scale by increasing habitat heterogeneity. Dams built by beaver (Castor canadensis) dramatically alter riparian landscapes throughout much of North America. In the central Adirondacks, New York, USA, ecosystem engineering by beaver leads to the formation of extensive wetland habitat capable of supporting herbaceous plant species not found else-where in the riparian zone. We show that by increasing habitat heterogeneity, beaver increase the number of species of herbaceous plants in the riparian zone by over 33% at a scale that encompasses both beaver-modified patches and patches with no history of beaver occupation. We suggest that ecosystem engineers will increase species richness at the landscape scale whenever there are species present in a landscape that are restricted to engineered habitats during at least some stages of their life cycle.

Wright, J. P., A. S. Flecker and C. G. Jones. 2003.
Local vs. landscape controls on plant species richness in beaver meadows.
Ecology. 84:3162-3173.
There is considerable interest in determining whether the species richness of communities is determined by forces controlling dispersal into patches that operate at the landscape scale, or forces controlling persistence that act at the local scale. Understanding the relative importance of these two classes of factors in controlling within-patch species richness is particularly important when patches are created via ecosystem engineering. In such cases, factors affecting the population dynamics or behavior of a single species could indirectly affect species richness if richness is controlled primarily by landscape-level factors. We used a combination of experimental mesocosms and field observations to determine whether species richness in beaver wetlands in the Adirondack Mountains (New York) is more strongly controlled by the position of the wetland in the landscape or by within-wetland hydrology. Drainage rate had a significant effect on both richness and composition in mesocosms, with well-drained treatments having significantly higher richness than poorly drained treatments. Seed germinated from the seed bank in sediments collected from different ponds showed relatively small differences in richness or community composition in mesocosms, suggesting a comparatively small effect of dispersal limitation on species richness. Experimental results were mirrored in a survey of 14 meadows over two years, which indicated that variability in water table depth was consistently a significant predictor of species richness, while meadow area and isolation showed little relation to richness. The survey also suggested that the number of years since beaver had abandoned a

site was a significant predictor of the number of species found in beaver meadows. The results indicate that species richness in beaver meadows is strongly controlled by local factors, but that the population dynamics of beaver could also potentially affect species richness by altering the age distribution of meadows across the landscape.

Wright, J. P., W. S. C. Gurney, C. G. Jones and J. C. G. 2004.
Patch dynamics in a landscape modified by ecosystem engineers.
Oikos. 105:336-348.
Ecosystem engineers, organisms that modify the environment, have the potential to dramatically alter ecosystem structure and function at large spatial scales. The degree to which ecosystem engineering produces large-scale effects is, in part, dependent on the dynamics of the patches that engineers create. Here we develop a set of models that links the population dynamics of ecosystem engineers to the dynamics of the patches that they create. We show that the relative abundance of different patch types in an engineered landscape is dependent upon the production of successful colonists from engineered patches and the rate at which critical resources are depleted by engineers and then renewed. We also consider the effects of immigration from either outside the system or from engineers that are present in non-engineered patches, and the effects of engineers that can recolonize patches before they are fully recovered on the steady state distribution of different patch types. We use data collected on the population dynamics of a model engineer, the beaver, to estimate the per-patch production rate of new colonists, the decay rate of engineered patches, and the recovery rate of abandoned patches. We use these estimated parameters as a baseline to determine the effects of varying parameters on the distribution of different patch types. We suggest a number of hypotheses that derive from model predictions and that could serve as tests of the model. (Author)

<u>Floodplain functions (and ecological relationships)</u>

Andersen, D. C. and D. J. Cooper. 2000.
Plant-herbivore-hydroperiod interactions: effects of native mammals on floodplain tree recruitment.
Ecological Applications. 10:1384-1399.
Floodplain plant-herbivore-hydroperiod interactions have received little attention despite their potential as determinants of floodplain structure and functioning. The authors used five types of exclosures to differentially exclude small-, medium-, and large-sized mammals from accessing Fremont cottonwood (Populus deltoides Marshall subsp. wizlizenii (Watson) Eckenwalder) seedlings and saplings growing naturally on four landform types at an alluvial reach on each of two rivers, the Green and Yampa, in Colorado and Utah. The two study reaches differed primarily as a result of flow regulation on the Green River, which began in 1962. Landforms were a rarely flooded portion of the alluvial plain, geomorphically active slow- and fast-water channel margin sites on the Yampa reach, and an aggrading side channel on the Green. Small-mammal live-trapping and observational data indicated that, with minor exceptions, the kinds of mammals eating cottonwood within each reach were identical. The authors monitored condition and fates of individual cottonwood plants from October 1993 through the 1997 growing season. Differences in survival and growth were noted both within and between reaches, and both due, to, and independent of, mammalian herbivory. Comparisons of cottonwood growth and survivorship among exclosures and between exclosures and controls indicated that a small

mammal, Microtus montanus, reduced seedling and sapling survivorship at the Green River reach, but to a lesser extent (seedlings) or not at all (saplings) on the Yampa reach. In contrast, reductions in sapling height increment attributable to medium- and large-sized herbivores were detected only at the Yampa site. They suggest that these differences are a result of (1) flow regulation allowing Microtus populations to escape the mortality normally accompanying the large, snowmelt-driven spring flood, as well as regulation promoting a herbaceous understory favorable to voles, and (2) greater browsing pressure from overwintering deer and elk at the Yampa reach, unrelated to flow regulation. Within areas used by foraging beaver, the probability of a sapling being cut by beaver was similar on the two reaches. This study suggests that changes in riparian plant-herbivore relationships due to shifts in river hydrology may be a common and important consequence of river regulation.

Brown, A. G. 2002.
Learning from the past: Palaeohydrology and palaeoecology.
Freshwater Biology. 47:817-829.
Attempts to increase European biodiversity by restoring rivers and floodplains are based on inadequate data on natural systems. This is particularly the case for NW European rivers because all catchments have been impacted by agriculture and river engineering. If river restoration is to have an ecological, as opposed to 'cosmetic' design basis then baseline models are required. However, this poses three questions; (a) what is the natural river-floodplain state, (b) how can it be defined and modelled and (c) can this state be recreated today? The first two questions can only be addressed by using palaeohydrological and palaeoecological data. A second and equally vital consideration is the stability/instability of any restored system to change in external forcing factors (e.g. climate) and in this context it may not be realistic to expect baseline models to provide equilibrium solutions but instead to define process-form domains. Over the last two decades evidence has accumulated that the natural state of lowland rivers in much of NW Europe was multi rather than single thread-braided, anastomosing or anabranching. Until recently our knowledge of floodplain palaeoecology was generally derived from pollen diagrams, which have source-area of problems and lack of taxonomic specificity. The precision and breadth of palaeoecological reconstruction (including richness and structure) has been greatly increased by the use of multiple palaeo-indicators including macrofossils, diatoms and beetles. The dynamics of small to medium sized, low-energy, predeforestation floodplains were dominated by disturbance (windthrow, beavers, etc.) and large woody debris. In order to compare the hydrogeomorphological basis of floodplain ecology, both temporally and spatially, a simple index of fluvial complexity is presented. Palaeoecological and geomorphological investigations have the potential to provide in-depth models of the natural range of channel conditions and sensitivity to external change that can be used to provide a scientific basis for floodplain restoration. There is also the possibility that floodplain-channel restoration may be a valuable tool in the mitigation of future geomorphological change forced by climatic instability.

Chapa-Vargas, L. and S. K. Robinson. 2007.
Nesting success of acadian flycatchers (Empidonax virescens) in floodplain forest corridors.
The Auk: a quarterly journal of ornithology. 124:1267-1280.
Reconnecting forest patches, including those of floodplain forest, often involves the creation of long, narrow corridors that have the potential to act as ecological traps for wildlife. We examined the effect of forest width and habitat composition of the landscapes immediately around nest

patches on survival and parasitism of 359 Acadian Flycatcher (Empidonax virescens) nests in the Cache River Bioreserve in southern Illinois. Nests were distributed among 19 floodplain forest corridors along a small river system that is being restored and reconnected along its original floodplain. The corridors spanned a range of widths (80-3,170 m) and varied with the presence or absence of natural water-related habitats (beaver ponds, backwater swamps, and creeks). Although nest success varied slightly between stages of the breeding cycle, confidence intervals overlapped, which suggests constant nest success throughout the breeding cycle. Nest survival was relatively high by regional standards but did not vary significantly with any of the landscape variables measured. Contrary to predictions, probabilities of brood parasitism decreased with increasing proportions of anthropogenic habitats surrounding nests. Probabilities of brood parasitism also decreased, but only slightly, as the breeding season progressed. Finally, Acadian Flycatcher nests were located significantly more often near natural (forest-water interface) edges than expected at random. Narrow corridors such as those along floodplain restoration projects do not necessarily create ecological traps for all forest species. Acadian Flycathcers, however, are one of the only forest-nesting Neotropical migrants that nest in narrow corridors and, therefore, may be less vulnerable to negative effects of fragmentation.

MacCracken, J. G. and A. D. Lebovitz. 2005.
Selection of in-stream wood structures by beaver in the Bear River, southwest Washington.
Northwestern Naturalist. 86:49-58.
[unedited] Many habitat restoration projects for Pacific salmon (Oncorhynchus spp.) have placed wood structures in streams. We observed beaver (Castor canadensis) consistently using three wood structures placed in the Bear River as foundations for dams, which provided pool habitat for juvenile salmon. Determining why beaver used some structures and not others could help to increase the efficacy of wood placement through use by beaver. We conducted an exploratory study using model selection procedures based on Akaike's information criteria to assess the hypothesis that there were characteristics of the wood structures and their immediate environment that influenced use by beaver. A literature review and field observations were used to develop seven logistic regression models and the parameters of those models were estimated with data from 55 in-stream wood structures. One model had overwhelming support (Akaike weight = 0.9801) as the best in the set of seven examined. Variables in that model described both in-stream characteristics (channel confinement; and distance to log jams, deep pools, and beaver bank dens) and riparian conditions (floodplain width and hillside slope). Structures used by beaver were in unconfined channels, farther from other logjams, closer to deep pools and bank dens, in wider floodplains, and with less steep hillsides. The logistic regression model is a resource selection probability function that may be useful in designing wood placement projects if restoration ecologists and managers wish to enlist the services of beaver.

McCollum, R. C. 1992.
Comparative use of lower, headwater, and beaver-impacted floodplains by swamp rabbits.
59:Auburn University.

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.

The effects of beaver activity were examined on several major ecosystem components and processes in boreal forest drainage networks in Quebec. The density of dams on the small streams averaged 10.6 dams/km; the streams retain up to 6,500 cu m of sediment per dam, and the wetted surface area of the channel is increased up to several hundred-fold. Beaver are also active in larger order streams, but their effects are most noticeable along riverbanks and in floodplains. Beaver ponds are important sites for organic matter processing; the stream metabolism index, a measure of ecosystem efficiency for the utilization or storage of organic inputs, is 1.63 for a pond on 2nd order Beaver Creek compared to 0.30 for the riffle upstream from it; the turnover length for particulate carbon is 1.2 km for the pond compared to 8.0 km for the riffle. Beaver-induced alterations to the structure and function of streams suggest that removal of beaver prior to 1900 had substantial effects on the dynamics of lotic ecosystems. It is suggested that current concepts of the organization and diversity of unaltered stream ecosystems in North America should recognize the keystone role of beaver, as drainage networks with beaver are substantially different in their biogeochemical economies than those without beaver.

Townsend, P. A. and D. R. Butler. 1996.
Patterns of landscape use by beaver on the lower Roanoke River floodplain, North Carolina.
Physical Geography. 17:253-269.
Between 1984 and 1993 beaver populations in the Roanoke River floodplain increased. Beaver water impoundment increased tenfold during this time. The beavers predominantly used sloughs or backswamps. The increase in beaver activity increased the length of beaver-pond edge and associated habitat within the floodplain. Areas containing baldcypress and water tupelo were most affected, because these areas are prone to flooding. Beaver activity may result in decreased forest regeneration because of flooding caused by impoundments and the growth of shrub-herbaceous "beaver meadows" along the edges of the ponds. lgh.

<u>Food habits and diet</u>

Baker, B. W. and B. S. Cade. 1995.
Predicting biomass of beaver food from willow stem diameters.
Journal of Range Management. 48:322-326.

Baker, B. W. 2003.
Beaver (Castor canadensis) in heavily browsed environments.
Lutra. 46:173-181.
Beaver (Castor canadensis) populations have declined or failed to recover in heavily browsed environments. I suggest that intense browsing by livestock or ungulates can disrupt beaver-willow (Salix spp.) mutualisms that likely evolved under relatively low herbivory in a more predator-rich environment, and that this interaction may explain beaver and willow declines. Field experiments in Rocky Mountain National Park, Colorado, USA, found the interaction of beaver and elk (Cervus elaphus) herbivory suppressed compensatory growth in willow. Intense elk browsing of simulated beaver-cut willow produced plants which were small and hedged with a high percentage of dead stems, whereas protected plants were large and highly branched with a low percentage of dead stems. Evaluation of a winter food cache showed beaver had selected woody stems with a lower percentage of leaders browsed by elk. A lack of willow stems suitable as winter beaver food may cause beaver populations to decline, creating a negative feedback

mechanism for beaver and willow. In contrast, if browsing by livestock or ungulates can be controlled, and beaver can disperse from a nearby source population, then beaver may build dams in marginal habitat which will benefit willow and cause a positive riparian response that restores proper function to degraded habitat. In a shrub-steppe riparian ecosystem of northwestern Colorado, USA, rest from overgrazing of livestock released herbaceous vegetation initiating restoration of a beaver-willow community. Thus, competition from livestock or ungulates can cause beaver and willow to decline and can prevent their restoration in heavily browsed riparian environments, but beaver and willow populations can recover under proper grazing management.

Baker, B. W., H. C. Ducharme, D. C. S. Mitchell, T. R. Stanley and H. R. Peinetti. 2005.
Interaction of beaver and elk herbivory reduces standing crop of willow.
Ecological Applications. 15:110-118.
Populations of beaver and willow have not thrived in riparian environments that are heavily browsed by livestock or ungulates, such as elk. The interaction of beaver and elk herbivory may be an important mechanism underlying beaver and willow declines in this competitive environment. We conducted a field experiment that compared the standing crop of willow three years after simulated beaver cutting on paired plants with and without intense elk browsing ([approximately]85% utilization rate). Simulated beaver cutting with intense elk browsing produced willow that was small (biomass and diameter) and short, with far fewer, but longer, shoots and a higher percentage of dead biomass. In contrast, simulated beaver cutting without elk browsing produced willow that was large, tall, and leafy, with many more, but shorter, shoots (highly branched) and a lower percentage of dead biomass. Total stem biomass after three years was 10 times greater on unbrowsed plants than on browsed plants. Unbrowsed plants recovered 84% of their pre-cut biomass after only two growing seasons, whereas browsed plants recovered only 6%. Thus, the interaction of beaver cutting and elk browsing strongly suppressed the standing crop of willow. We predict that a lack of willow suitable as winter food for beaver can cause beaver populations to decline, creating a feedback mechanism that reduces beaver and willow populations. Thus, intense herbivory by ungulates or livestock can disrupt beaver-willow mutualisms that naturally occur in less competitive environments.

Belovsky, G. E. 1984.
Summer diet optimization by beaver.
American Midland Naturalist. 111:209-222.

Darbyshire, S. and L. Consaul. 1999.
Wildlife sometimes benefits from purple loosestrife.
Trail and Landscape. 33:181-184.
Although commonly thought of as merely a pest plant species, purple loosestrife is now suspected to be part of the diet of beaver on islands in the Ottawa River, Ontario, Canada. The authors indicate that this is the only reference they have found of beaver or other native wildlife consuming purple loosestrife. pcp.

Doucet, C. M. and J. M. Fryxell. 1993.
The Effect of Nutritional Quality on Forage Preference by Beavers.
Oikos. 67:201-208.

We investigated the effect of nutritional parameters on preference by beavers (Castor canadensis) for five forage species. Cafeteria style experiments demonstrated that preferences ranked in the following descending order: trembling aspen (Populus tremuloides), white water lily (Nymphaea odorata), raspberry (Rubus idaeus), speckled alder (Alnus rugosa) and red maple (Acer rubrum). We assessed forage quality by determining dry matter, energy, crude protein, sodium, fibre and lignin contents as well as the digestibility of dry matter, energy and protein. Mean retention times of the diets in the gut of the beaver were estimated using a solid marker added to the forage. The mean retention times of aspen, raspberry and water lily were significantly shorter than those of alder and maple. Forage preferences were not significantly correlated with any single nutritional parameter. A linear programming (LP) model was used to determine if several of the parameters, when examined simultaneously, could predict forage preference. The LP model, using energetic and digestive constraints, correctly predicted the ranking of four of the five forage species in the diet of the beaver. These data suggest that beavers, like other vertebrate herbivores, select a diet which maximizes long-term energy intake, subject to digestive limitations.

Fryxell, J. M. and C. M. Doucet. 1993.
Diet choice and the functional response of beavers.
Ecology. 74:1297-1306.

Fryxell, J. M. and C. M. Doucet. 1993.
Diet Choice and the Functional-Response of Beavers.
Ecology. 74:1297-1306.
We investigated the effects of changing sapling availability on foraging selectivity and cutting rates by beavers in large experimental enclosures. As predicted by an energy-maximizing contingency model, the mean size of saplings cut by beavers increased with distance from the lodge and was positively correlated with sapling density. Species selectivity was also positively correlated with sapling density. Trembling aspen (Populus tremuloides) was preferred to speckled alder (Alnus rugosa), and red maple (Acer rubrum) was the least preferred species. The functional responses of beavers presented with saplings of a single species and of similar size differed from those recorded in trials with a single species of saplings of variable sizes and from trials with three species of saplings of variable sizes. Size-selective foraging by beavers reduced the maximum rate of sapling cutting at high sapling densities relative to the single-size trials, but both treatments showed similar cutting rates at low sapling densities. Species-selective foraging by beavers reduced cutting rates at low sapling densities relative to the single-species trials, but both treatments showed similar cutting rates at high sapling densities. Species-selective foraging introduced a slight inflection in the functional response curve for preferred species, which could have a stabilizing effect on trophic interactions.

Fryxell, J. M., S. M. Vamosi, R. A. Walton and C. M. Doucet. 1994.
Retention Time and the Functional-Response of Beavers.
Oikos. 71:207-214.
We investigated the effects of interspecific variation in forage retention time on rates of food intake and energy gain by beavers. Ad libitum intake rates by beavers were a hyperbolic function of retention time in the digestive tract and a positive linear function of beaver live mass. Mean retention times of animals on mixed diets varied proportionately with diet composition. Daily

intake rates by beavers provided with monospecific stands of trembling aspen or speckled alder saplings showed a monotonically declerating (type 2) functional response to changes in sapling biomass density. Daily intake rates differed between these two forage species, such that alder with a long retention time produced lower consumption rates than aspen with a short retention time. Net rates of energy gain were also reduced when animals foraged on species with long retention time. Our results suggest that interspecific variation in retention time plays an important role in determining rates of dry matter intake and energy gain by beavers, which could influence the stability of beaver-vegetation interactions.

Ganzhorn, J. U. and M. Harthun. 2000.
Food selection by beavers (Castor fiber albicus) in relation to plant chemicals and possible effects of flooding on food quality.
Journal of Zoology. 251:391-398.
The goal of this study was to investigate whether or not beavers Castor fiber albicus improve the quality of their food plants by dam construction, resulting in periodic flooding associated with the deposition of mud and nutrients on their feeding grounds. For this, food selection of beavers was studied in relation to plant chemicals in the Spessart mountains (central Germany). The concentrations of the preferred plant chemicals were compared between individuals of the same plant species growing in areas that were flooded periodically and areas that were edaphically dry. Plants eaten by beavers contained higher concentrations of nitrogen and lower concentrations of neutral detergent fibre and hemicellulose than neighbouring plants that were not eaten. Neither nitrogen concentrations nor neutral detergent fibre contents differed significantly between plants from the dry and wet sites. Thus, beaver activities did not improve the chemical quality of their food plants.

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.
Canadian Field-Naturalist. 119:591-593.
We report observations of Beavers (Castor canadensis) foraging and feeding on discarded Chinook Salmon (Oncorhynchus tshawytscha) carcasses within the confines of the Susitna River drainage in southcentral Alaska on three separate occasions between 1999 and 2004. In all three instances, Beavers were observed actively seeking out freshly discarded carcasses or transporting "fresh" salmon carcasses in their mouths. In one instance, Beavers were seen using their dextrous forefeet to "handle" chunks of salmon while hunched over carcasses and in this case we actually witnessed Beavers "chewing" and ingestion was assumed. In the other two instances, Beavers were observed swimming with salmon carcasses in their mouths. Though unique within the framework of Beaver foraging ecology, we suggest this behavior may be a fairly common strategy employed by Beavers in Alaskan streams and rivers to take advantage of a seasonally superabundant source of protein.

Hagerman, A. E. and C. T. Robbins. 1993.
Specificity of tannin-binding salivary proteins relative to diet selection by mammals.
Canadian Journal of Zoology. 71:628-633.

Kimball, B. A. and K. R. Perry. 2008.

Manipulating beaver (Castor canadensis) feeding responses to invasive tamarisk (Tamarix spp.).
Journal of Chemical Ecology. 34:1050-1056.
To evaluate methods for promoting consumption of tamarisk plants by beavers (Castor canadensis), we determined the feeding responses by captive beavers to diets that contained tannins and sodium chloride (hereafter referred to as tamarisk diet). In two-choice tests, beavers consumed equivalent quantities of tamarisk diet and control diet. Treatment with polyethylene glycol and fructose did not increase beaver preferences for the tamarisk diet. When offered the choice of control diet and casein hydrolysate-treated control diet, beavers strongly avoided the latter, showing feeding deterring activity of casein hydrolysate. However, when tamarisk diet was the alternative to the deterrent treatment, beavers consumed similar quantities of the two diets. Finally, beaver foraging preferences for actual plant cuttings were assessed. Casein hydrolysate application to cuttings of black poplar (Populus nigra) and Scouler's willow (Salix scouleriana) reduced browsing of these highly preferred species and promoted a marked increase in browsing of tamarisk (Tamarix ramosissima). These results suggest that casein hydrolysate treatment of desirable riparian plant species such as Salix and Populus may promote beaver foraging of invasive tamarisk.

Nolet, B. A. and P. J. Van-Der-Veer. 1995.
A linear programming model of diet choice of free-living beavers.
Netherlands Journal of Zoology. 45:315-337.

Northcott, T. H. 1972.
Water lilies as beaver food.
Oikos. 23:408-409.
NINE MILLION TONS OF SALT WERE USED IN 1970 TO CLEAN SNOW FROM HIGHWAYS. THESE QUANTITIES OF SALT HAVE ADVERSE EFFECTS ON PUBLIC DRINKING WATER SUPPLIES, WILDLIFE, VEGETATION, LAKES, AND RIVERS. A MIXTURE OF CALCIUM CHLORIDE AND SODIUM CHLORIDE LOWERS THE FREEZING POINT OF THE BRINE SOLUTION AND BREAKS THE BOND BETWEEN ICE AND ROAD. THE DANGER IS THAT HIGH CONCENTRATIONS OF SALTS MAY OVERLOAD DISPERSAL MECHANISMS. IT IS ESTIMATED THAT 25 TO 50 PER CENT OF THE SALT INFILTRATES TO THE GROUNDWATER. HIGH RUNOFF CONTAMINATES MANY SHALLOW WELLS AND CAN ALSO AFFECT WILDLIFE BY DISTURBING BODY PROCESSES. SALT IN WATER SUPPLIES MAY BE HARMFUL TO PEOPLE WITH HEART DISEASE OR THOSE ON LOW SALT DIETS. SALINE SOIL WATER WILL INHIBIT THE PLANTS INTAKE OF WATER AND MAKE SOIL LESS PERMEABLE. SUBSTANTIAL LOSSES OF ROADSIDE TREES HAVE OCCURRED. SALT MAY ALSO DISRUPT THE VERTICAL MIXING IN LAKES AND PONDS THROUGH DENSITY STRATIFICATION AND DEGRADE FISH ENVIRONMENTS.

Parker, J. D., C. C. Caudill and M. E. Hay. 2007.
Beaver herbivory on aquatic plants.
Oecologia. 151:616-625.
Herbivores have strong impacts on marine and terrestrial plant communities, but their impact is less well studied in benthic freshwater systems. For example, North American beavers (Castor canadensis) eat both woody and non-woody plants and focus almost exclusively on the latter in

summer months, yet their impacts on non-woody plants are generally attributed to ecosystem engineering rather than herbivory. Here, we excluded beavers from areas of two beaver wetlands for over 2 years and demonstrated that beaver herbivory reduced aquatic plant biomass by 60%, plant litter by 75%, and dramatically shifted plant species composition. The perennial forb lizard's tail (Saururus cernutts) comprised less than 5% of plant biomass in areas open to beaver grazing but greater than 50% of plant biomass in beaver exclusions. This shift was likely due to direct herbivory, as beavers preferentially consumed lizard's tail over other plants in a field feeding assay. Beaver herbivory also reduced the abundance of the invasive aquatic plant Myriophyllum aquaticum by nearly 90%, consistent with recent evidence that native generalist herbivores provide biotic resistance against exotic plant invasions. Beaver herbivory also had indirect effects on plant interactions in this community. The palatable plant lizard's tail was 3 times more frequent and 10 times more abundant inside woolgrass (Scirpus cyperinus) tussocks than in spatially paired locations lacking tussocks. When the protective foliage of the woolgrass was removed without exclusion cages, beavers consumed nearly half of the lizard's tail leaves within 2 weeks. In contrast, leaf abundance increased by 73-93% in the treatments retaining woolgrass or protected by a cage. Thus, woolgrass tussocks were as effective as cages at excluding beaver foraging and provided lizard's tail plants an associational refuge from beaver herbivory. These results suggest that beaver herbivory has strong direct and indirect impacts on populations and communities of herbaceous aquatic plants and extends the consequences of beaver activities beyond ecosystem engineering.

Veraart, A. J., B. A. Nolet, F. Rosell and P. P. de Vries. 2006.
Simulated winter browsing may lead to induced susceptibility of willows to beavers in spring.
Canadian Journal of Zoology. 84:1733-1742.
Browsing may lead to an induced resistance or susceptibility of the plant to the herbivore. We tested the effect of winter browsing by Eurasian beavers (Castor fiber L., 1758) on food quality of holme willows (Salix dasyclados Wimm.) in and after the following growth season. Shrubs were pruned in February, and new shoots from these (cut) shrubs were compared with those of untreated (uncut) ones in May and November. The shoots were analysed for dry matter, nitrogen, acid detergent fibre, and total phenolics. In May, the leaves from the cut treatment had a better food quality (more water, more nitrogen, and less phenolics) than those from the uncut one. There was in part also a systemic response, with lower total phenolics in both the cut and untreated parts of pruned shrubs (uncut-cut) than in the uncut shrubs. In November, we did not find significant differences in biochemistry of bark among cut, uncut, or uncut-cut treatments. These results are in accordance with a cafeteria experiment in the field: in May the beavers preferred shoots from the cut treatment, but in November they showed no preference. The results suggest that willows invest in compensatory growth rather than a defence response early in the regrowing phase.

Genetics

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

Bailey, J. K., J. A. Schweitzer, B. J. Rehill, R. L. Lindroth, G. D. Martinsen, T. G. Whitham and J. K. Biley. 2004.
Beavers as molecular geneticists: a genetic basis to the foraging of an ecosystem engineer.
Ecology. 85:603-608.
Ecological genetics is increasingly recognized as critical to understanding interactions among organisms and ecosystem processes. Using a common garden with pure and hybrid cottonwood trees of known genotype, two years of field surveys, and a cafeteria feeding experiment, we link introgression of Fremont genetic markers, condensed tannins (a genetically based plant trait), and foraging by beavers. These data support two major arguments. First, hybridization is an important mechanism for the transmission of ecologically functional traits. Second, links between a genetically based plant trait in a dominant riparian-forest tree species and the foraging behavior of beavers, an ecosystem engineer, emphasize that genetically based plant traits can directly and indirectly link population, community, and ecosystem processes.

Crawford, J. C., Z. Liu, T. A. Nelson, C. K. Nielsen and C. K. Bloomquist. 2008.
Microsatellite analysis of mating and kinship in beavers (Castor canadensis).
Journal of Mammalogy. 89:575-581.
Monogamy is rare among mammals and molecular investigations have revealed that many socially monogamous species participate in extrapair mating. The North American beaver (Castor canadensis) is a socially monogamous species that exhibits classic monogamous behavior, generally living in discrete colonies composed of a mated pair and their offspring. We examined genetic relationships within and among beaver colonies for 2 populations in Illinois to investigate average relatedness within colonies, occurrences of extrapair mating within or between colonies, and the influence of geographic distance on intercolony relatedness. Seven microsatellite loci developed for the beaver were used to estimate relatedness and parentage for 55 beavers in central Illinois and 72 beavers in southern Illinois. Average within-colony relatedness varied widely in both populations, ranging from 0.04 to 0.64 in central Illinois and from 0.16 to 0.41 in southern Illinois. Colonies were composed primarily of 1st- and 2nd-order relatives, but included unrelated individuals. Paternity analysis revealed that 5 (56%) of 9 litters had been sired by >=2 males. Extrapair mating frequently occurred between members of neighboring colonies in southern Illinois. In contrast to long-held views that beavers are genetically monogamous and colonies are typically 1st-order relatives, we documented a wide range of relationships among colony members and multiple paternity in >50% of litters. (Author)

Doyon, C., V. L. Trudeau, B. M. Hibbert, L. A. Howes and T. W. Moon. 2003.
mRNA analysis in flattened fauna: obtaining gene-sequence information from road-kill and game-hunting samples.
Canadian Journal of Zoology. 81:692-698.
Whether gene-sequence information could be obtained using mRNA from road-kill and hunting samples was investigated. Adipose tissue was used to clone cDNA fragments of the hormone leptin and brain tissue was used for the enzyme glutamic acid decarboxylase (GAD). Tissues collected from road-killed animals were used to clone leptin from RNA samples of raccoon (Procyon lotor) and woodchuck (Marmota monax). We were able to extract RNA and clone GAD67 from samples of masked shrew (Sorex cinereus), although the time of death was unknown. We collaborated with hunters who provided tissues from which we cloned leptin and GAD isoforms from beaver (Castor canadensis), red squirrel (Tamiasciurus hudsonicus), black

bear (Ursus americanus), and moose (Alces alces americana). Molecular phylogenetic analyses confirmed that the sequences obtained did not result from contamination. A time-course experiment showed that even 24 h after the death of rats, sufficient mRNA remains to amplify leptin from adipose tissue. These results suggest that road-kill and hunting samples could be used as a valuable source of gene-sequence information.

Genest, F. B., P. Morisset and R. P. Patenaude. 1979.
The chromosomes of the Canadian beaver *Castor canadensis*.
Canadian Journal of Genetics and Cytology. 21:37-42.

Graphodatsky, A. S., V. R. Eremina, V. N. Orlov, N. S. Bulatova and V. L. Lavrov. 1991.
Numerous chromosome rearrangements in the karyotype evolution of the beavers (Castor, Castoridae, Rodential) of the Old and New World.
Zoologicheskii Zhurnal. 70:84-91.

Kuehn, R., G. Schwab, W. Schroeder and O. Rottmann. 2000.
Differentiation of Castor fiber and Castor canadensis by noninvasive molecular methods.
Zoo Biology. 19:511-515.
The aim of the study was to develop a simple and reliable method for differentiation of the two phenotypic, very similar Eurasian and North American beavers. Hair bulbs were plucked as tissue samples from the fur of living animals. The mitochondrial cytochrome b locus was amplified by polymerase chain reaction and sequenced. The fragments of the two species differed at 44/41 nucleotide sites. RsaI recognised two mutations, resulting in a restriction fragment length polymorphism that seems to be species specific, as could be revealed by the banding pattern.

Lizarralde, M., J. Escobar and G. Deferrari. 2004.
Invader species in Argentina: A review about the beaver (Castor canadensis) population situation on Tierra del Fuego ecosystem.
Interciencia. 29:352-356, 403.
Beavers (Castor canadensis) were introduced at Isla Grande, Terra del Fuego, Argentina, in 1946. Suitable feeding and lodging sites, coupled with lack of natural predators or competitors favored rapid population growth and range expansion. This paper shows the current population status and landscape modifications induced by beavers in these southern ecosystems. Beavers are now found in all streams in the Andean and extra-Andean areas, and in nearly all aquatic habitats on Isla Grande as well as other Chilean islands of tire Tierra del Fuego archipelago (70000km2). Areas with low gradient in small streams are more densely occupied than those in slope valleys. Densities are similar to those in the Northern Hemisphere. Extensively colonized habitats showed 0.7 active beaver colonies per km2. Based on their different beaver occupancy patterns and frequency of colony sites, four land capability classes (A, B, C and D) were established to use in planning and resource management. The highest densities were found in classes C and D (4.7 and 5.6 colony sites per km2) indicating that both these areas had the greatest potential,for beaver production. Beaver-altered sites had higher levels of organic and inorganic N, suggesting that seasonal hydrological changes could be affecting nitrification and denitrification, also resulting in accumulated organic C and P in the stream channel. Beaver ponds may be considered sources of essential nutrients (P and N) and C. Chromosome analysis showed no differences with

the North American karyotype. Genetic structure and variability of the beaver population are analyzed.

Williams, C. L., S. W. Breck and B. W. Baker. 2004.
Genetic methods improve accuracy of gender determination in beavers.
Journal of Mammalogy. 85:1145-1148.
Gender identification of sexually monomorphic mammals can be difficult. We used analysis of zinc-finger protein (Zfx and Zfy) DNA regions to determine gender of 96 beavers (Castor canadensis) from 3 areas and used these results to verify gender determined in the field. Gender was correctly determined for 86 (89.6%) beavers. Incorrect assignments were not attributed to errors in any one age or sex class. Although methods that can be used in the field (such as morphological methods) can provide reasonably accurate gender assignments in beavers, the genetic method might be preferred in certain situations.

Habitat relationships

Allen, A. W. 1983.
Habitat Suitability Index (HSI) Models: Beaver.

Apple, L. L. 1983.
The use of beavers in riparian/aquatic habitat restoration in a cold desert, gully-cut stream system: A case history.
18:29-35.

Apple, L. L. 1985.
Riparian habitat restoration and beavers.
120:489-490.

Apple, L. L., B. H. Smith, J. D. Dunder and B. W. Baker. 1984.
The Use of Beavers for Riparian/Aquatic Habitat Restoration of Cold Desert, Gully-Cut Stream Systems in Southwestern Wyoming.

Baker, B. W., D. L. Hawksworth and J. G. Graham. 1992.
Wildlife Habitat Response to Riparian Restoration on the Douglas Creek Watershed.

Progress and preliminary results are reported following two years of study to evaluate wildlife and habitat response to varied livestock grazing, channel morphology, and beaver abundance in the Douglas Creek watershed. The performance the yellow warbler and beaver habitat suitability index (HSI) models.

Barnes, D. M. and A. U. Mallik. 1997.
Habitat factors influencing beaver dam establishment in a northern Ontario watershed.
Journal of Wildlife Management. 61:1371-1377 | 1371.
Beaver (Castor canadensis) dam-site selection studies traditionally have relied on plant composition. To understand how habitat factors influence dam establishment, we compared 9 plant composition and size categories and their spatial distribution with 4 physical features at 15

active dams, 15 abandoned dams, and 12 no-dam sites. To establish pre-dam vegetation densities, plots downstream and upstream from impoundments were averaged. We found beaver relied on both physical (upstream watershed area and stream cross-sectional area) and vegetation (shoreline concentrations of woody plants with diameters 1.5-4.4 cm) factors in choosing dam sites. The model designed by McComb et al. (1990) was not effective in predicting dam sites in northern Ontario, therefore, we recommend that managers test the model's regional accuracy in determining site locations.

Beier, P. and R. H. Barrett. 1987.
Beaver habitat use and impact in Truckee River Basin, California.
Journal of Wildlife Management. 51:794-799.
Stepwise logistic regression was used to identify factors important for habitat use by beavers on streams. Increasing stream width and depth and decreasing gradient had the strongest positive effects on habitat use; food-availability variables added little explanatory power. Some abandoned colony sites appeared to have been located on physically-unsuitable habitat, whereas others appeared to be physically-suitable sites abandoned due to resource depletion. The fact that few unused or uncolonized reaches were misclassified as suitable habitat suggests that suitable habitat has been saturated. Impact of beaver on woody plants was assessed for 8 forage species. Local extinction of quaking aspen (Populus tremuloides) and black cottonwood (P. trichocarpa) occurred on 4-5% of stream reaches. Willow (Salix spp.) showed good vigor despite heavy use in most reaches.

Boyce, M. S. 1981.
Habitat ecology of an unexploited population of beavers in interior Alaska.
Proceedings of the Worldwide Furbearer Conference. 155-186.

Breck, S. W., K. R. Wilson and D. C. Andersen. 2001.
The demographic response of bank-dwelling beavers to flow regulation: a comparison on the Green and Yampa rivers.
Canadian Journal of Zoology. 79:1957-1964.
The authors assessed the effects of flow regulation on the demography of beavers (Castor canadensis) by comparing the density, home-range size, and body size of bank-dwelling beavers on two sixth-order alluvial river systems, the flow-regulated Green River and the free-flowing Yampa River, from 1997 to 2000. Flow regulation on the Green River has altered fluvial geomorphic processes, influencing the availability of willow and cottonwood, which, in turn, has influenced the demography of beavers. Beaver density was higher on the Green River (0.5-0.6 colonies per kilometre of river) than on the Yampa River (0.35 colonies per kilometre of river). Adult and subadult beavers on the Green River were in better condition, as indicated by larger body mass and tail size. There was no detectable difference in home range size, though there were areas on the Yampa River that no beavers used. The authors attribute the improved habitat quality on the Green River to a greater availability of willow. They suggest that the sandy flats and sandbars that form during base flows and the ice cover that forms over winter on the Yampa River increase the energy expended by the beavers to obtain food and increase predation risk and thus lowers the availability of woody forage.

Collins, T. C. 1977.

Population characteristics and habitat relationships of beavers, *Castor canadensis*, in northwest Wyoming.
University of Wyoming.

Cunningham, J. M., A. J. K. Calhoun and W. E. Glanz. 2007.
Pond-breeding amphibian species richness and habitat selection in a beaver-modified landscape.
Journal of Wildlife Management. 71:2517-2526.
Beaver (Castor canadensis) activity creates wetland habitats with varying hydroperiods important in maintaining habitat diversity for pond-breeding amphibians with significantly different breeding habitat requirements. We documented pond-breeding amphibian assemblages in 71 freshwater wetlands in Acadia National Park, Maine, USA. Using 15 variables describing local pond conditions and wetland landscape characteristics, we developed a priori models to predict sites with high amphibian species richness and used model selection with Akaike's Information Criterion to judge the strength of evidence supporting each model. We developed single-species models to predict wood frog (Rana sylvatica), bullfrog (R. catesbeiana), and pickerel frog (R. palustris) breeding site selection. Sites with high species richness were best predicted by 1) connectivity of wetlands in the landscape through stream corridors and 2) wetland modification by beaver. Wood frog breeding habitat was best predicted by temporary hydroperiod, lack of fish, and absence of current beaver activity. Wood frog breeding was present in abandoned beaver wetlands nearly as often as in nonbeaver wetlands. Bullfrog breeding was limited to active beaver wetlands with fish and permanent water. Pickerel frog breeding sites were best predicted by connectivity through stream corridors within the landscape. As beavers have recolonized areas of their former range in North America, they have increased the number and diversity of available breeding sites in the landscape for pond-breeding amphibians. The resulting mosaic of active and abandoned beaver wetlands both supports rich amphibian assemblages and provides suitable breeding habitat for species with differing habitat requirements. Land managers should consider the potential benefits of minimal management of beavers in promoting and conserving amphibian and wetland diversity at a landscape scale. (Author)

Curtis, P. D. and P. G. Jensen. 2004.
Habitat features affecting beaver occupancy along roadsides in New York State.
Journal of Wildlife Management. 68:278-287 | 278-288.
Characterizing habitat features that influence beaver (Castor canadensis) occupancy along roadsides may have important implications for managing damage to roads Caused by beaver activity. We initiated this study to develop proactive and long-term approaches to deal with nuisance beaver along roadsides. From June to October 1997 and 1998, we sampled 316 roadside sites in New York state, USA-216 sites where beaver occupied the roadside area and 100 unoccupied sites. We used stepwise logistic regression to identify habitat variables associated with beaver occupancy along roadsides. We evaluated regression models through measures of sensitivity and specificity. The logistic function retained the percentage of roadside area devoid of woody vegetation, stream gradient, the interaction between these 2 variables, and stream width in the final model. Precluding beaver occupancy along highways would necessarily involve large-scale removal of woody vegetation that would be impractical in all but the most intensive management scenarios. However, beaver habitat assessment adjacent to roads max, be

a useful tool for designing new highways, prioritizing culvert replacements, and developing proactive plans for beaver damage management.

Dalbeck, L., B. Luescher, D. Ohlhoff and B. L□scher. 2007.
Beaver ponds as habitat of amphibian communities in a central European highland.
Amphibia Reptilia. 28:493-501.
The Eurasian beaver Castor fiber, formerly occurred across the Palaearctic, but was nearly eradicated in the 19th century. Due to reintroductions in the 20th century, beaver populations are increasing and now extend into highland areas. Natural still waters are scarce in highlands of Central Europe. Therefore the question arises, "Are beaver ponds essential habitats for amphibians?", especially since fishes, predators of amphibian larval stages, also inhabit beaver ponds. We investigated the amphibian fauna of one typical valley in the Eifel, that was colonized by beavers in 1981, and compared areas with and without beaver ponds. All anuran species of the region occupied beaver ponds, including species that were absent (Alytes obstetricans, Bufo bufo and Rana kl. esculenta) or rare (Rana temporaria) in natural waters. Alytes obstetricans obviously benefited from pond construction and the removal of trees by beavers which leads to sunny plots along the slopes of the valley, crucial habitat for this species. The urodelans Salamandra salamandra, Triturus alpestris and Triturus helveticus were widely distributed in beaver ponds. Our results show clearly, that beaver altered landscapes offer high quality habitats for amphibians in our study area. Due to a considerable increase of habitat heterogeneity in impounded streams, the predator Salmo trutta was not able to extirpate the amphibian fauna. We conclude that the historic effects of beavers need to be considered for a proper understanding of patterns of amphibian distribution and habitat requirements in Central European Highlands. Furthermore, beaver-created landscapes will be of future relevance for conservation of endangered species, like Alytes obstetricans.

Davis, J. R. and D. C. Guynn. 1993.
Activity and Habitat Utilization of Beaver Colonies in South Carolina.
47:299-310.
Objectives were to describe monthly, seasonal, and yearly activities of beaver in the Piedmont of South Carolina, determine sizes of areas impacted by beaver, compare lake colony beaver activity to an adjacent stream colony, and describe habitat utilization by beaver in the Piedmont of South Carolina.

Degraaf, R. M. and M. Yamasaki. 2003.
Options for managing early-successional forest and shrubland bird habitats in the northeastern United States.
Forest Ecology and Management. 185:179-191.
Historically, forests in the northeastern United States were disturbed by fire, wind, Native American agriculture, flooding, and beavers (Castor canadensis). Of these, wind and beavers are now the only sources of natural disturbance. Most disturbance-dependent species, especially birds, are declining throughout the region whereas species affiliated with mature forests are generally increasing or maintaining populations. Disturbance must be simulated for conservation of early-successional species, many of which are habitat specialists compared to those associated with mature forests. Both the maintenance of old fields and forest regeneration are needed to conserve brushland species. Regenerating forest habitats are more ephemeral than other woody

early-successional habitats. The types and amounts of early-successional habitats created depend on the silvicultural system used, patch size selected, time between regeneration cuts, and rotation age. We recommend that group selection and patch cuts should be at least 0.8 ha, and patches should be generated approximately every 10-15 years depending on site quality. Regeneration of intolerant and mid-tolerant tree species should be increased or maintained in managed stands. Also, frost pockets, unstocked, or poorly-stocked stands can provide opportunities to increase the proportion of early-successional habitats in managed forests.

Dieter, C. D. and T. R. McCabe. 1989.
Habitat Use by Beaver Along the Big Sioux River in Eastern South Dakota.
Riparian Resource Manage. 135-140.
Habitat use by beavers Castor canadensis was investigated during 1985 and 1986 in grazed and ungrazed areas along the Big Sioux River in eastern South Dakota. Almost half (48%) of the trees in ungrazed areas were small (diameter at breast height < 7.5 cm), but a majority (58%) of the trees in grazed areas had large diameters (diameter > 30 cm). Beaver activity was evident on 280 of 2369 (11.8%) trees (diameter > 2.5 cm) and 756 of 7794 (9.7%) stems (diameter </= 2.5 cm) sampled. A greater proportion of trees were cut by beavers in ungrazed than in grazed areas. Beaver did not select tree species for cutting according to availability. Trees cut by beaver were significantly smaller in diameter than uncut trees. Mean distance from water of cut trees was less than for uncut trees. Over half (52%) of the trees damaged by beaver either resprouted or remained alive and standing.

Fryxell, J. M. 2001.
Habitat suitability and source-sink dynamics of beavers.
Journal of Animal Ecology. 70:310-316.
1.Theory suggests that territorial species should share many of the same dynamical characteristics as metapopulations, including asynchronous local dynamics, potential for stochastic extinction of the population when rates of successful dispersal fall below mortality risk, and critical importance of the ratio of suitable to unsuitable habitat for long-term persistence. These propositions were tested on a population of beavers in Algonquin Provincial Park, Ontario, which has been continuously monitored over 11 years. 2. Results showed that the total population was considerly less variable than local abundance at 14 beaver colonies, due to asynchrony among local populations. This suggests that local ecological interactions were more important in determining year-to-year variation in beaver numbers than broad-scale environmental processes, such as weather. 3. Of the local colonies, 20% were never abandoned over 11 years, although there was considerable turnover among adults. Offspring production exceeded adult abundance at five source colonies, which did not quite compensate for negative net production at nine sink colonies. These observations were consistent with predictions of spatially structured models of territoriality incorporating local variation in habitat suitability. Mean colony size and probability of recurrence from year-to-year were associated with local food availability, indicating that trophic interactions were important in determining local population dynamics. 4. The beaver population in Algonquin declined steadily over the study period, however, suggesting that spatial and demographic processes were insufficient to stabilize abundance over time. This is consistent with predictions of spatially structured models of territoriality in which suitable and unsuitable habitats are interspersed. It is hypothesized that

long-term decline in habitat suitability is induced by acceleration of woody plant succession due to selective foraging by beavers.

Gill, D. 1972.
The evolution of a discrete beaver habitat in the MacKenzie River Delta, Northwest Territories.
Canadian Field-Naturalist. 86:233-239.

Gray, M. H. and D. H. Arner. 1977.
The Effects of Channelization on Furbearers and Furbearer Habitat.
31:259-265.
Biological data were collected over a 3 year period (1974-1977) from an old channelized segment (55 years), an unchannelized segment and a newly channelized segment (4 years) of the Luxapalila River in Mississippi and Alabama. This study revealed that furbearer habitat in the channelized segments has not recovered to the level exhibited in the unchannelized segment. Indices of furbearer abundance were obtained by night lighting and sign counting. Beaver (Castor canadensis), mink (Mustela vison), muskrat (Ondatra zibethicus), and raccoon (Procyon lotor) were more numerous in the unchannelized segment than in either the old or newly channelized segments.

Harris, H. T. 1991.
Habitat use by dispersing and transplanted beavers in western Montana.
40:Univ. of Montana.

Henry, D. B. 1967.
Age structure, productivity, and habitat characteristics of the beaver in northeastern Ohio.
Ohio State University.

Hood, G. A., S. E. Bayley and W. Olson. 2007.
Effects of prescribed fire on habitat of beaver (Castor canadensis) in Elk Island National Park, Canada.
Forest Ecology and Management. 239:200-209.
Fire, flooding, herbivory, and the effects of climate are all topical issues for today's land managers. Effective resource management requires a balance among these processes, which in turn, requires a better understanding of their interactions. Beaver (Castor canadensis) are strong colonizers and have been successfully reintroduced to much of their former range. Prescribed fire has also been introduced in many areas as a management tool to restore ecological function. Resource managers have often assumed fire would also benefit non-target species like beaver; however, its effect on beaver has not been well studied. In this study, part of a broader project in Elk Island National Park, Canada, we examine the effect of prescribed fire on beaver lodge occupancy in the context of high ungulate populations. Elk Island National Park has an active beaver population, high ungulate densities, and a well-established prescribed fire program. We examine whether frequency, size, and timing of bums influence beaver lodge occupancy and the establishment of new lodges. Since 1979, over 51% of the park (99.3 km2) has been burned with prescribed fire. By comparing lodge occupancy over a period prior to and after a series of prescribed bums, we analyzed beaver occupancy rates pre- and post-burn. Our results show that repeated burning dramatically decreases beaver lodge occupancy, and that even after one bum

the number of active colonies declines and does not recover to pre-fire populations. Especially when combined with drought and herbivory, prescribed fire does not improve beaver habitat.

Howard, R. J. 1982.
Beaver habitat classification in Massachusetts.
Transactions of the Northeast Section of the Wildlife Society. 39:17.
Models developed from principal component and discriminant regression analyses were 90% and 95% successful, respectively, in predicting the presence or absence of beaver on a stream. Models were 75% and 80% successful in predicting the number of beaver colonies on a 1km stream section.

Howard, R. J. and J. S. Larson. 1985.
A stream habitat classification system for beaver.
Journal of Wildlife Management. 49:19-25.

Huey, W. S. 1956.
Management of furbearing animals: Effects of habitat on beaver productivity.

Jensen, P. G., P. D. Curtis, M. E. Lehnert and D. L. Hamelin. 2001.
Habitat and structural factors influencing beaver interference with highway culverts.
Wildlife Society Bulletin. 29:654-664 | 654.
The plugging of highway culverts by beavers (Castor canadensis) creates roadside impoundments that damage and sometimes flood the roadbed. Continually mitigating these problem sites requires considerable time, money, and resources from town, country, and state highway departments. The authors initiated this study to develop proactive and long-term approaches to deal with nuisance beavers along roadsides. Their specific objective was to compare culvert and habitat features at plugged and nonplugged culverts. From June to October 1997 and 1998, they sampled 216 roadside sites in New York state: 113 sites where beavers plugged the highway culvert and 103 sites where beavers did not plug the culvert but instead constructed an upstream or downstream dam. They used stepwise logistic regression (SLR) to identify key variables associated with plugged culverts. They evaluated classification rates of regression models with measures of sensitivity and specificity. For the combined data set, the logistic function retained culvert inlet opening area (m~2~) and stream gradient in the final model. Based on the two variables, the model correctly classified 79% of the sites. The results of the study indicated that installing oversized culverts would have the greatest influence on discouraging beaver plugging activity. Prorated over the service life of culverts, the installation of oversized culverts by highway departments may be more cost-effective than trapping, debris removal, or other short-term options to manage beaver damage to roads.

Lindstrom, J. W. and W. A. Hubert. 2004.
Ice processes affect habitat use and movements of adult cutthroat trout and brook trout in a Wyoming foothills stream.
North American Journal of Fisheries Management. 24:1341-1352.
Habitat use and movements of 25 adult cutthroat trout Oncorhynchus clarkii and 25 adult brook trout Salvelinus fontinalis from fall through winter 2002-2003 were assessed by means of

radiotelemetry in a 7-km reach of a Rocky Mountains foothills stream. Temporal dynamics of winter habitat conditions were evaluated by regularly measuring the features of 30 pools and 5 beaver Castor canadensis ponds in the study reach. Groundwater inputs at three locations raised mean daily water temperatures in the stream channel during winter to 0.2-0.6 degrees Celsius and kept at least 250 m of the downstream channel free of ice, but the lack of surface ice further downstream led to the occurrence of frazil ice and anchor ice in pools and unstable habitat conditions for trout. Pools in segments that were not affected by groundwater inputs and beaver ponds tended to be stable and snow accumulated on the surface ice. Pools throughout the study reach tended to become more stable as snow accumulated. Both cutthroat trout and brook trout selected beaver ponds as winter progressed but tended to use lateral scour pools in proportion to their availability. Tagged fish not in beaver ponds selected lateral scour pools that were deeper than average and stable during winter. Movement frequencies by tagged fish decreased from fall through winter, but some individuals of both species moved during winter. Ice processes affected both the habitat use and movement patterns of cutthroat trout and brook trout in this foothills stream.

MacCracken, J. G. 2000.
Wildlife response to salmon habitat enhancements on the Bear River, southwest Washington.
Northwestern Naturalist. 81:82.
In 1997, large wood was added to 13 sites in the Bear River of southwest Washington and four kilometes of riparian red alder (Alnus rubra) forest were thinned and planted to conifer. Small mammal and amphibian abundance was similar (P=0.45) between thinned and control red alder stands from 1997-99. Beaver (Castor canadensis) activity increased and dam construction was often associated with an introduced large wood structure. edited by pcp.

McRae, G. and C. J. Edwards. 1994.
Thermal characteristics of Wisconsin headwater streams occupied by beaver: Implications for brook trout habitat.
American Fisheries Society. Transactions.

Munther, G. L. 1982.
Beaver management in grazed riparian ecosystems (Wildlife impact, low gradient stream habitats, Montana).
Proceedings of the Wildlife-Livestock Relationships Symposium: held at Coeur d'Alene, Idaho, April 20-22, 1981. 234-241.

Neff, D. J. 1956.
Ecological effects of habitat abandonment by beavers on a high mountain valley in Colorado.
Colorado State University.

Neff, D. J. 1956.
Beaver investigations: Ecological effects of beaver habitat abandonment - Annual forage production.

Payne, F. J. 1961.

Effects of beaver flooding of alder woodcock habitat on the Moosehorn National Wildlife Refuge.
University of Maine.

Pearson, A. M. 1960.
A study of the growth and reproduction of the beaver, Castor canadensis, Kuh, correlated with the quality and quantity of some habitat factors.
University of British Columbia.

Rebertus, A. J. 1986.
Bogs as beaver habitat in north-central Minnesota.
American Midland Naturalist. 116:240-245 | 240.
Although beavers frequently colonize lakes and streams that are adjacent to bog areas, few (Castor canadensis Huhl.) researchers have mentioned that beavers are capable of colonizing bogs that lack open water. In a l00-sq km area surveyed for beaver activity, one-third of the active colonies were in bogs and two-thirds were in lakes and rivers. From 1979 to 1981, the percent of colonies in bogs increased from 29% to 36%. Of 481 bogs in the study area, 200 (42%) had current or previous history of beaver activity (colony sites and work areas). At 101 bogs (21%), dam construction in seepage zones created flowages. Most impoundments were built at brushy minerotrophic sites. Moats were used at 99 bogs (21%), where beavers preferred sedge-moss cover and avoided tall shrub and wooded cover. The results show that bogs are suitable habitat for beavers.

Reese, K. P. 1976.
Avian community structure of beaver pond, hardwood, and pine habitats in the Piedmont region of South Carolina.
Clemson University.

Robel, R. J., L. B. Fox and K. E. Kemp. 1993.
Relationship between habitat suitability index values and ground counts of beaver colonies in Kansas.
Wildlife Society Bulletin. 21:415-421 | 415.

Sanner, C. J. 1987.
Effects of beaver on stream channels and Coho salmon habitat, Kenai Peninsula, Alaska.
Department of Fisheries and Wildlife. 81:Oregon State University.

Snyder, C. D., J. A. Young and B. M. Stout III. 2006.
Aquatic habitats of Canaan Valley, West Virginia: Diversity and environmental threats.
Northeastern Naturalist. 13:333-352.
We conducted surveys of aquatic habitats during the spring and summer of 1995 in Canaan Valley, WV, to describe the diversity of aquatic habitats in the valley and identify issues that may threaten the viability of aquatic species. We assessed physical habitat and water chemistry of 126 ponds and 82 stream sites, and related habitat characteristics to landscape variables such as geology and terrain. Based on our analyses, we found two issues likely to affect the viability of aquatic populations in the valley. The first issue was acid rain and the extent to which it

potentially limits the distribution of aquatic and semi-aquatic species, particularly in headwater portions of the watershed. We estimate that nearly 46%, or 56 kilometers of stream, had pH levels that would not support survival and reproduction of Salvelinuw fontinalis (brook trout), one of the most acid-tolerant fishes in the eastern US. The second issue was the influence of Castor canadensis (beaver) activity. In the Canaan Valley State Park portion of the valley, beaver have transformed 4.7 kilometers of stream (approximately 17% of the total) to pond habitat through their dam building. This has resulted in an increase in pond habitat, a decrease in stream habitat, and a fragmented stream network (i.e., beaver ponds dispersed among stream reaches). In addition, beaver have eliminated an undetermined amount of forested riparian area through their foraging activities. Depending on the perspective, beaver-mediated changes can be viewed as positive or negative. Increases in pond habitat may increase habitat heterogeneity with consequent increases in biological diversity. In contrast, flooding associated with beaver activity may eliminate lowland wetlands and associated species, create barriers to fish dispersal, and possibly contribute to low dissolved oxygen levels in the Blackwater River. We recommend that future management strategies for the wildlife refuge be viewed in the context of these two issues, and that the responses of multiple assemblages be incorporated in the design of refuge management plans.

Stevens, C. E., C. A. Paszkowski and G. J. Scrimgeour. 2006.
Older is better: beaver ponds on boreal streams as breeding habitat for the wood frog.
Journal of Wildlife Management. 70:1360-1371.
Succession of stream ponds mediated by beaver (Castor canadensis) damming and foraging in riparian zones may contribute to changes in amphibian populations. Our study examined the use of beaver ponds by the wood frog (Rana sylvatica) in a network of boreal streams in west-central Alberta, Canada. We quantified relations between breeding populations of wood frogs estimated from call surveys and pond age and riparian canopy cover, and we compared an index of juvenile recruitment to metamorphosis estimated with pitfall trap captures between new (< 10 yr) and old (> 25 yr) beaver ponds. We also conducted an in-pond enclosure experiment to determine if differences in physicochemical conditions of new versus old ponds influenced larval performance. Regression and Akaike's Information Criterion model averaging indicated that both density and calling intensity of male wood frogs at beaver ponds had a negative relationship with percent riparian canopy cover and had a positive relationship with pond age. The best a priori statistical models, however, included riparian canopy cover rather than pond age as a significant covariate. Old ponds had reduced riparian canopy and greater abundance of submergent vegetation, thermal degree-days, and dissolved oxygen concentrations compared to newly formed ponds. While survival of larval wood frogs in enclosures did not differ between pond age classes, growth and development rates in old ponds were greater than in new ponds. In addition to warmer water in old ponds, results from a laboratory experiment suggest that higher concentrations of dissolved oxygen characteristic of old ponds can enhance larval growth rates. Older beaver ponds may support more breeding wood frogs due to adult selection for open-canopy ponds and the associated larval environments favourable for high rates of juvenile recruitment. Forest management that protects beaver and their food supplies may also promote healthy populations of boreal amphibians.

Suzuki, N. and W. C. McComb. 1998.

Habitat classification models for beaver (Castor canadensis) in the streams of the central Oregon Coast Range.
Northwest Science. 72:102-110.
In Drift Creek Basin, Lincoln County, Oregon beavers built dams in areas with wide valley floors; narrow, low gradient streams; high grass and sedge cover; and low red alder and shrub cover. The authors used stream width, gradient, and valley floor width to develop a Habitat Suitability Index model for Drift Creek Basin. lgh.

Taylor, G. B., J. A. Barnes and D. H. Van Lear. 1994.
Impacts of beaver (Castor canadensis carolinensis) on riparian ecosystems, water quality, and trout habitat in the Chauga River Drainage.
Society of American Foresters National Convention Proceedings. 1993:534-535.

Welsh, R. G. and D. Muller-Schwarze. 1989.
Experimental habitat scenting inhibits colonization by beaver, Castor canadensis.
Journal of Chemical Ecology. 15:887-893.

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. 111:217-222.
The author studied differences in home range sizes in beavers living in ponds, lakes, and rivers. Beavers living in rivers had larger home ranges than those living in ponds, but no differences were evident between those living in rivers and in lakes or between those in ponds and in lakes. When non-family beavers were excluded from the analysis no differences in home range size were found among the habitats. Activity in the core areas did not differ among habitats in summer, but in fall, core area activity was greater in lakes than in rivers regardless of whether non-family beavers were included. lgh.

Wilkinson, R. N. 1988.
A habitat evaluation and management plan for a riparian ecosystem.
University of North Texas.

Williams, R. M. 1965.
Beaver habitat and management.
Idaho Wildlife Review. 17:3-7.
Of the 44,000 miles of Idaho streams, 50% is unsuitable because slopes are too steep and 17% because of use by man. Beaver population density has been one colony per 1.3 to 1.7 miles during the past five years, based on surveys made annually of more than 400 miles of Idaho streams.

Winkle, P. L., W. A. Hubert and F. J. Rahel. 1990.
Relations between brook trout standing stocks and habitat features in beaver ponds in southeastern Wyoming.
North American Journal of Fisheries Management. 10:72-79.

Human dimensions

Destefano, S. and R. Deblinger. 2005.
Wildlife as valuable natural resources vs. intolerable pests: a suburban wildlife management model.
Urban Ecosystems. 8:179-190.
Management of wildlife in suburban environments involves a complex set of interactions between both human and wildlife populations. Managers need additional tools, such as models, that can help them assess the status of wildlife populations, devise and apply management programs, and convey this information to other professionals and the public. We present a model that conceptualizes how some wildlife populations can fluctuate between extremely low (rare, threatened, or endangered status) and extremely high (overabundant) numbers over time. Changes in wildlife abundance can induce changes in human perceptions, which continually redefine species as a valuable resource to be protected versus a pest to be controlled. Management programs thatincorporate a number of approaches and promote more stable populations of wildlife avoid the problems of the resource versus pest transformation, are less costly to society, and encourage more positive and less negative interactions between humans and wildlife. We presenta case example of the beaver Castor canadensis in Massachusetts to illustrate how this model functions and can be applied. (Author)

Enck, J. W. and T. L. Brown. 1996.
Citizen participation approaches for successful beaver management.
Human Dimensions of Wildlife. 1:78-79.
Wildlife managers in New York believe that new approaches are needed for encouraging and including public input into beaver management decisions. Successful citizen participation would allow stakeholders to help develop the decision-making process as well as review and comment on the decision. pcp.

Enck, J. W., N. A. Connelly and T. L. Brown. 1996.
Public Attitudes Toward Wildlife and Its Accessibility. Public Attitudes Toward Beaver and Beaver Management: Management Response to Beaver Complaints in WMU 21.
New York [State]. Department of Environmental Conservation. Annual Report. 1996:44.
Information is synthesized from a reanalysis of three previous studies of stakeholder's (general public, landowners, and highway superintendents) beaver-related attitudes and experiences in New York (Purdy and Decker 1985, Enck et al. 1988, Enck et al. 1992). Regression models were developed to predict acceptance of beavers and acceptance of actions to address nuisance beaver problems.

Enck, J. W., N. A. Connelly and T. L. Brown. 1997.
Acceptance of beaver and actions to address nuisance beaver problems in New York.
Human Dimensions of Wildlife. 2:60-61.
The authors developed regression models predicting acceptance of beaver and acceptance of actions to address nuisance beaver problems using data from three mail surveys conducted in New York from 1985-1992. klf.

Hadidian, J. 2003.

Managing conflicts with beaver in the United States: an animal welfare perspective.
Lutra. 46:217-222.
As had happened earlier in Europe, the American beaver (Castor canadensis) was almost completely extirpated from its historic range because of human exploitation. Anywhere from 50 to 400 million beaver may have occurred throughout North America prior to the arrival of Europeans. Today, the population in the United States has recovered from unknown historic lows to a point where conflicts with humans have notably increased. The standard approach to resolving human-beaver conflicts has been to kill beaver and destroy their structures. From both an environmental as well as animal welfare perspective this approach is regarded as short-sighted. This paper addresses the issue of humane and environmentally responsible beaver conflict management, and identifies alternatives that control the problems beaver cause without necessitating their removal. It also addresses the benefits created by the presence of beaver in even highly urbanized ecosystems and details the strategy of one animal protection organization, the Humane Society of the United States, to educate the public about the beneficial role these animals can play.

Haider, S. and K. Jax. 2007.
The application of environmental ethics in biological conservation: a case study from the southernmost tip of the Americas.
Biodiversity and Conservation. 16:2559-2573.
Biological conservation is not only about facts and technical measures concerning ecology, rather it must also consider values. This pertains to both the balancing of various human interests and also to the ethical evaluation of human actions towards nature. Here we discuss how environmental ethics can be incorporated into conservation decisions, and what implications the inclusion of ethical valuation has for the practice of conservation biology. While this is done mostly on a rather abstract level, we illustrate this here by applying ethical theory to a case study: the options for management of the introduced North American beaver (<i>Castor canadensis</i>) in the very south of Chile (Navarino Island). The beaver is an exotic species to the area and has substantially altered the ecological systems of the region. We discuss different options for dealing with the beaver (eradicate, control, tolerate, promote) from the viewpoint of anthropocentric environmental ethics and biocentric ethics. The results of our analysis demonstrate the value of ethical discussions in clarifying and underpinning arguments for and against specific actions. At the same time, they also show that ethical arguments do not decrease the need for sound scientific data but, on the contrary, may even increase this demand. We also highlight that the conclusions regarding adequate actions to be taken vary depending on the specific ethical theory embraced.

Hebblewhite, M., C. A. White, C. G. Nietvelt, J. A. McKenzie, T. E. Hurd, J. M. Fryxell, S. E. Bayley and P. C. Paquet. 2005.
Human activity mediates a trophic cascade caused by wolves.
Ecology. 86:2135-2144.
Experimental evidence of trophic cascades initiated by large vertebrate predators is rare in terrestrial ecosystems. A serendipitous natural experiment provided an opportunity to test the trophic cascade hypothesis for wolves (Canis lupus) in Banff National Park, Canada. The first wolf pack recolonized the Bow Valley of Banff National Park in 1986. High human activity partially excluded wolves from one area of the Bow Valley (low-wolf area), whereas wolves

made full use of an adjacent area (high-wolf area). We investigated the effects of differential wolf predation between these two areas on elk (Cervus elaphus) population density, adult female survival, and calf recruitment; aspen (Populus tremuloides) recruitment and browse intensity; willow (Salix spp.) production, browsing intensity, and net growth; beaver (Castor canadensis) density; and riparian songbird diversity, evenness, and abundance. We compared effects of recolonizing wolves on these response variables using the log response ratio between the low-wolf and high-wolf treatments. Elk population density diverged over time in the two treatments, such that elk were an order of magnitude more numerous in the low-wolf area compared to the high-wolf area at the end of the study. Annual survival of adult female elk was 62% in the high-wolf area vs. 89% in the low-wolf area. Annual recruitment of calves was 15% in the high-wolf area vs. 27% without wolves. Wolf exclusion decreased aspen recruitment, willow production, and increased willow and aspen browsing intensity. Beaver lodge density was negatively correlated to elk density, and elk herbivory had an indirect negative effect on riparian songbird diversity and abundance. These alternating patterns across trophic levels support the wolf-caused trophic cascade hypothesis. Human activity strongly mediated these cascade effects, through a depressing effect on habitat use by wolves. Thus, conservation strategies based on the trophic importance of large carnivores have increased support in terrestrial ecosystems.

Jonker, S. A. 2003.
Values and attitudes of the public toward beaver conservation in Massachusetts.
Dissertation Abstracts International. Section B: Physical Sciences and Engineering. 64:2458-259.
In Massachusetts both human and beaver population levels are rising, beaver damage complaints are escalating, and beaver management options are restricted by the 1996 Wildlife Protection Act. Employing the Cognitive Value Hierarchy, this study enhances understanding of the public's value orientations, attitudes, and norms regarding human-beaver conflicts in Massachusetts. a mailback questionnaire was sent to a random sample of 5,563 residents in three geographic regions in Massachusetts and to residents who submitted a beaver complaint to Masswildlife in 1999/2000 (47.3% overall response rate). Results indicate that respondents believe beaver are an important part of the natural environment and they have a right to exist. Respondents also support some form of beaver management. Most respondents believe that beaver-related damage in Massachusetts has either increased or remained the same over the past five years, and indicated a preference for fewer beaver, regardless of experience with beaver damage. Respondents' attitudes are influenced by their experience with beaver damage, perceptions of extent of beaver damage, and tolerance of beaver. as severity of beaver damage was perceived to increase, respondents were more willing to accept lethal management/control of beaver. Respondents characterized by a "wildlife-use" orientation expressed a greater willingness to accept lethal action in response to beaver activity than respondents characterized by a "wildlife-protection" orientation. this relationship was partially mediated when respondents believed beaver damage had increased and/or they preferred to see fewer beaver in Massachusetts. Value orientations proved to be predictive of both attitudes and norms, thus validating the propositions of the Cognitive Value Hierarchy. Results confirm the importance of understanding and monitoring public attitudes, norms, perceptions, and tolerance in a longitudinal framework and coupling this information with biological data to determine trends in relation to increases in beaver populations and human-beaver conflicts. the concepts and causal relationships posed by the Cognitive Value Hierarchy can provide information to link attitudes, norms, and values of wildlife stakeholder groups with socially acceptable management

strategies. Replicating, expanding, and applying this framework to other wildlife species, and in different socio-political environments, can enhance the effectiveness and applicability of this theoretical perspective in understanding and resolving complex human-wildlife conflicts.

Jonker, S. A., R. M. Muth, J. F. Organ, R. R. Zwick and W. F. Siemer. 2006.
Experiences with beaver damage and attitudes of Massachusetts residents toward beaver.
Wildlife Society Bulletin. 34:1009-1021.
As stakeholder attitudes, values, and management preferences become increasingly diverse, managing human-wildlife conflicts will become more difficult. This challenge is especially evident in Massachusetts, USA, where furbearer management has been constrained by passage of a ballot initiative that outlawed use of foothold and body-gripping traps except in specific instances involving threats to human health or safety. Without regulated trapping, beaver (Castor canadensis) populations and damage attributed to them have increased. To develop an understanding of public attitudes regarding beaver-related management issues, we surveyed a random sample of Massachusetts residents in the spring of 2002 within 3 geographic regions where beaver are prevalent, as well as all individuals who submitted a beaver-related complaint to the Massachusetts Division of Fisheries and Wildlife in 1999 and 2000. We found that respondents held generally positive attitudes toward beaver. Respondents who experienced beaver-related problems tended to have less favorable or negative attitudes toward beaver than people who did not experience beaver damage. Attitudes toward beaver became increasingly negative as the severity of damage experienced by people increased. We believe continued public support for wildlife conservation will require implementation of strategies that are responsive to changing attitudes of an urban population and within social-acceptance and biological carrying capacities.

Loker, C. A., D. J. Decker and S. J. Schwager. 1999.
Social acceptability of wildlife management actions in suburban areas: 3 cases from New York.
Wildlife Society Bulletin. 27:152-159 | 152.
Despite notable successes, wildlife damage management in suburban situations is widely perceived as difficult because of the vocal resistance of some suburban residents to many mitigation measures. We examined suburban residents' experiences with, concerns about, and acceptance of management actions for white-tailed deer (Odocoileus virginianus), beaver (Castor canadensis), or Canada geese (Branta canadensis) in three areas of New York state. We considered four types of interventions which represented degrees of invasiveness to the animals of concern: human behavior modification, nonlethal-noninvasive, nonlethal-invasive, and lethal. Results demonstrated that residents' concerns about wildlife were elevated by increasingly severe problem experiences. In addition, residents' acceptance of invasive and lethal methods to resolve wildlife problems in suburban areas was higher than many wildlife managers might expect. Contrary to our predictions, acceptance of invasive and lethal methods was more strongly related to concerns about nuisance and economic damage issues than to concerns about health and safety issues. Our results provide useful information to wildlife professionals for management planning and communication regarding problem-causing wildlife in suburban areas.

McKinstry, M. C. and S. H. Anderson. 1999.
Attitudes of private-and public-land managers in Wyoming, USA, toward beaver.
Environmental Management. 23:95-101.

Researchers sent a mail survey concerning management of beaver in Wyoming to 5265 private-land managers and 124 public land managers in 1993. Primary concerns about beaver damage included, in order of decreasing importance, blocked irrigation ditches; girdled timber; blocked culverts; and flooded pastures, roads, crops, and timber. Primary benefits that landowners believed resulted from beaver were in order of importance, elevated water tables, increased riparian vegetation, and increased stock-watering opportunities. Perceived benefits and detriments of beaver were similar for managers of public and private holdings. klf.

Organ, J. F. and M. R. Ellingwood. 2000.
Wildlife stakeholder acceptance capacity for black bears, beavers, and other beasts in the east.
Human Dimensions of Wildlife. 5:63-75.
The formal concept of wildlife stakeholder acceptance capacity (WSAC) in wildlife management is less than a generation old. The genesis of wildlife management in North America occurred during a time when populations of many wildlife species were low, their habitats were altered and degraded, and the human population was rapidly urbanizing. The focus of wildlife management was to restore wildlife populations and habitats. Once restored, wildlife managers strove to maintain populations at levels within biological carrying capacities (BCC) and provide benefits to a relatively narrow range of stakeholders. In recent years, cultural changes associated with a predominantly suburban society have led to conflicts with traditional wildlife management approaches and broadened the stakeholder base. Wildlife managers have had to consider the interests of a wider stakeholder base that supports a diversity of often conflicting expectations, while relying on traditional funding sources. For certain species, management for WSAC has taken priority over management for BCC. This scenario is particularly focused in the northeast United States where human population densities are some of the highest in the nation. The authors explore the current state of knowledge of WSAC for certain species in the east, and review the tools being used for monitoring and assessment. They discuss adequacy of these approaches and offer suggestions for incorporating WSAC into wildlife management planning and operations. They consider the implications of WSAC to the future of wildlife management in North America.

Perry, C. 1945.
Beaver crisis in the Northeast.
American Forests. 51:72-73.
The "seamy side" of beaver restoration, including destruction of trees intended for reforestation, damage to trout streams, flooding of highways, and interference with city water supplies. Conservation officers quoted to the effect that there is little room for beavers in Massachusetts. Recent history in New York from a publication already noticed in WILDLIFE REVIEW (32, Nov. 1941, pp. 40-41). The statement is rather strong but the recommendations boil down to management. Conclusions: "Beavers may be 'friends of the forest,' but in the Northeast they certainly are not friends of the farmer, the railroad man, the highway engineer, or the lumberman; in many areas they are 'misplaced weeds.' The big problem is to keep them in locations where they belong. But it is doubtful if this can be accomplished short of immense expense, or without increased controlled trapping and transplanting of many areas remote from civilization, or through concentrated use of beavers on flood control and water conservation projects as is now done in some regions of the country."

Snodgrass, J. W. 1997.
Temporal and spatial dynamics of beaver-created patches as influenced by management practices in a south-eastern North American landscape.
Journal of Applied Ecology. 34:1043-1056.
Beavers create habitat diversity across catchment landscapes by impounding small streams. This increased habitat diversity leads to increased species richness of plants and animals in small streams. As managers work to balance conflicting management goals (e.g. protection of timber and human structures versus maintenance of biological diversity) the influence of beaver population management practices on habitat availability needs to be assessed. Two initial concerns are: (i) the effect of different levels of management on the availability of beaver created habitats; and (ii) whether relationships developed in one region apply to other regions. To address these questions, historical aerial photography was used to determine the extent and rate of impoundment of streams by beavers (<i>Castor canadensis</i>) over the 77000 ha Savanna River Site on the Upper Coastal Plain of South Carolina during a 40-yr period of beaver population recovery. Between 1950 and 1983, beaver populations were protected from trapping and hunting. From 1983 to the present, beaver numbers were reduced by fatal trapping, to protect roads, railroads and timber. Trapped beavers were assigned to specific colonies associated with beaver-created patches in the landscape, and growth rates and size after management of individual patches receiving different levels of management were compared. Results from this study were also compared with previous studies conducted in Minnesota. Growth rate, patch size following management, and the composition of habitat types within patches were not related to management activity, suggesting that the levels of management used in this study did not influence the temporal dynamics of beaver-created patches. The extent and rate of beaver impoundment at the Savanna River Site was less than that reported from central North American landscapes over comparable periods. These results have the following implications for management: (i) management activities should be monitored on a regional basis; (ii) conflicting beaver population management goals should be addressed, evaluated and balanced; and (iii) beavers do not present a threat to flowing-water species in south-eastern North America and need not be controlled for this reason.

Zinn, H. C., M. J. Manfredo, J. J. Vaske and K. Wittmann. 1998.
Using normative beliefs to determine the acceptability of wildlife management actions.
Society and Natural Resources. 11:649-662 | 649. Taylor & Francis.

The authors use a normative approach to describe and evaluate public opinion on acceptable management actions toward mountain lions, beavers, and coyotes. The results of the study point out circumstances that are likely to generate conflict over certain management policies and allow more confident generalization about how the public will respond to different management actions. lgh.

Hydrology

Andersen, D. C. and D. J. Cooper. 2000.
Plant-herbivore-hydroperiod interactions: effects of native mammals on floodplain tree recruitment.
Ecological Applications. 10:1384-1399.

Floodplain plant-herbivore-hydroperiod interactions have received little attention despite their potential as determinants of floodplain structure and functioning. The authors used five types of exclosures to differentially exclude small-, medium-, and large-sized mammals from accessing Fremont cottonwood (Populus deltoides Marshall subsp. wizlizenii (Watson) Eckenwalder) seedlings and saplings growing naturally on four landform types at an alluvial reach on each of two rivers, the Green and Yampa, in Colorado and Utah. The two study reaches differed primarily as a result of flow regulation on the Green River, which began in 1962. Landforms were a rarely flooded portion of the alluvial plain, geomorphically active slow- and fast-water channel margin sites on the Yampa reach, and an aggrading side channel on the Green. Small-mammal live-trapping and observational data indicated that, with minor exceptions, the kinds of mammals eating cottonwood within each reach were identical. The authors monitored condition and fates of individual cottonwood plants from October 1993 through the 1997 growing season. Differences in survival and growth were noted both within and between reaches, and both due, to, and independent of, mammalian herbivory. Comparisons of cottonwood growth and survivorship among exclosures and between exclosures and controls indicated that a small mammal, Microtus montanus, reduced seedling and sapling survivorship at the Green River reach, but to a lesser extent (seedlings) or not at all (saplings) on the Yampa reach. In contrast, reductions in sapling height increment attributable to medium- and large-sized herbivores were detected only at the Yampa site. They suggest that these differences are a result of (1) flow regulation allowing Microtus populations to escape the mortality normally accompanying the large, snowmelt-driven spring flood, as well as regulation promoting a herbaceous understory favorable to voles, and (2) greater browsing pressure from overwintering deer and elk at the Yampa reach, unrelated to flow regulation. Within areas used by foraging beaver, the probability of a sapling being cut by beaver was similar on the two reaches. This study suggests that changes in riparian plant-herbivore relationships due to shifts in river hydrology may be a common and important consequence of river regulation.

Cunningham, J. M., A. J. K. Calhoun and W. E. Glanz. 2006.
Patterns of beaver colonization and wetland change in Acadia National Park.
Northeastern Naturalist. 13:583-596.
The return of Castor canadensis (beaver) to areas of their former range has restored a natural disturbance regime to wetland landscapes in North America. We used aerial photographs to study wetland creation and modification by beaver in Acadia National Park, ME, during a period of beaver population expansion (19441997). We quantified the change in the number of available ponded wetlands in the landscape during the study period and documented an 89% increase in ponded wetlands between 1944 and 1997. Spatial and temporal patterns of beaver colonization and changes in wetland vegetation and hydrology were recorded at six time periods (1944, 1953, 1970, 1979, 1985, and 1997) for 33 beaver-created wetlands for which we had current amphibian assemblage data. Beaver colonization generally converted forested wetlands and riparian areas to open water and emergent wetlands, resulting in significant increases in the percentage of open water and emergent wetland habitat and a decrease in the percentage of forested wetland area at the study sites. Temporal colonization of beaver wetlands initially favored large sites occurring lower in the watersheds; sites that were impounded later were generally smaller, higher in the watershed, and more likely to be abandoned by the end of our study. Our results suggest that beaver have not only increased the number of available breeding sites in the landscape for pond-

breeding amphibians, but also the resulting mosaic of active and abandoned beaver wetlands is likely to provide suitable breeding habitat for a diversity of species.

Danell, K., T. Willebrand and L. Baskin. 1998.
Mammalian herbivores in the boreal forests: their numerical fluctuations and use by man.
Conservation Ecology. 2:1-20.
The authors present an account of the population fluctuations of mammalian herbivores occurring in the boreal forests of the Nearctic and Palaearctic and their interrelation with humans. The boreal forests support rich natural resources that have been used over centuries by mankind for survival. The mammalian species are the most important resource that have provided man with food and products of commercial importance like antlers and hides. Their impact on plant succession, and their role in increasing the wetland mosaic and altering the hydrology of important ecosystems is also significant. These mammalian herbivores exhibit fluctuating cycles that are evident on different trophic levels. There are three types of fluctuations. The first two groups contain species with regular fluctuations and the third group contains species with irregular fluctuations. Thus, a variation in population size that lacks stable resource-dependent equilibrium seems to be characteristic of population fluctuations of many large ungulates. This study indicated that forest management that reduces the structural and spatial diversity at the stand, as well as at the landscape, level affects boreal forest habitats. Management of silvicultural that supports same age trees improves conditions for species favoring young forest stands, but it makes the situation worse for species that depend on old-growth forests. Another aim of management is the attempt at successful increase of population sizes of mammals. However, this population increase might go out of control leading to destabilization and destruction. Therefore it can be concluded that management of boreal forest ecosystems should be both substantial and long lasting.

Ford, T. E. and R. J. Naiman. 1988.
Alteration of Carbon Cycling by Beaver: Methane Evasion Rates from Boreal Forest Streams and Rivers.
Canadian Journal of Zoology. 66:529-533.
In boreal forest drainage networks, beaver (Castor canadensis) apparently influence the biogeochemical cycling of carbon by creating conditions of sediment accumulation in streams, providing anoxic conditions suitable for significant methanogenesis. To test this assumption the author measured methane evasion rates in streams, ranging in size from first to sixth order, in the Matamek River drainage network, Quebec, Canada. Evasion rates varied between 0.04 and 4.41 g C (CH_4) per square meter/yr. There was no correlation between stream size or water temperature and evasion rate. However, methane evasion was 33-fold greater in beaver ponds than at other sites, representing 3.6% of the measured annual carbon output. In contrast, methane evasion accounted for only 0.05-0.5% of the annual carbon output from sites not modified by beaver.

Lizarralde, M., J. Escobar and G. Deferrari. 2004.
Invader species in Argentina: A review about the beaver (Castor canadensis) population situation on Tierra del Fuego ecosystem.
Interciencia. 29:352-356, 403.

Beavers (Castor canadensis) were introduced at Isla Grande, Terra del Fuego, Argentina, in 1946. Suitable feeding and lodging sites, coupled with lack of natural predators or competitors favored rapid population growth and range expansion. This paper shows the current population status and landscape modifications induced by beavers in these southern ecosystems. Beavers are now found in all streams in the Andean and extra-Andean areas, and in nearly all aquatic habitats on Isla Grande as well as other Chilean islands of tire Tierra del Fuego archipelago (70000km2). Areas with low gradient in small streams are more densely occupied than those in slope valleys. Densities are similar to those in the Northern Hemisphere. Extensively colonized habitats showed 0.7 active beaver colonies per km2. Based on their different beaver occupancy patterns and frequency of colony sites, four land capability classes (A, B, C and D) were established to use in planning and resource management. The highest densities were found in classes C and D (4.7 and 5.6 colony sites per km2) indicating that both these areas had the greatest potential,for beaver production. Beaver-altered sites had higher levels of organic and inorganic N, suggesting that seasonal hydrological changes could be affecting nitrification and denitrification, also resulting in accumulated organic C and P in the stream channel. Beaver ponds may be considered sources of essential nutrients (P and N) and C. Chromosome analysis showed no differences with the North American karyotype. Genetic structure and variability of the beaver population are analyzed.

Mitsch, W. J., J. W. Day and J. W. Day Jr. 2004.
Thinking big with whole-ecosystem studies and ecosystem restoration - a legacy of H.T. Odum. Ecological Modelling. 178:133-155.
Whole-ecosystem studies are in situ ecological studies and experiments of such a spatial and temporal scale as to include most if not all processes of the ecosystem. Principles of self-organization and self-design are key to whole-ecological function and often do not occur as vibrantly or conclusively at smaller scale experiments. Ecological feedback caused by organisms (e.g., beavers, plants that manage hydrology, ecosystem engineers, top-down control), pulses caused by events such as fire and floods, and emergent ecosystem properties caused by human wastes, recycling, and hydrologic modification are difficult if not impossible to be properly studied in small-scale experiments. Large-scale whole-ecosystem studies were pioneered in the 1960s and 1970s by H.T. Odum and colleagues with large drop nets in Texas coastal bays, rain forests enclosures in Puerto Rico, created coastal ponds in North Carolina, and sewage application to cypress swamps in Florida. The study in Florida investigated effects of wastewater additions to wetland function in cypress domes but unexpected fire in the experimental area led to adaptive research and the study of fire in field research and models. More recently we have been engaged in whole-ecosystem experiments, partially inspired by the work of Odum, at created wetlands in northeastern Illinois to investigate effects of water turnover on ecosystem function and in Ohio to provide insight on the long-range large-scale effects of hydrology and macrophyte planting on ecosystem function. We have also carried out major ecosystem-scale studies in coastal Louisiana, investigating the value of these ecological systems in treating wastewater and restoring lost landscape in coastal Louisiana. These studies in the Midwest and Mississippi delta form the basis of determining design standards on creating and restoring wetlands in the Mississippi River Basin to reduce the Gulf of Mexico hypoxia and regain many lost ecosystem functions over a large part of North America. [copyright] 2004 Elsevier B.V. All rights reserved.

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.
The effects of beaver activity were examined on several major ecosystem components and processes in boreal forest drainage networks in Quebec. The density of dams on the small streams averaged 10.6 dams/km; the streams retain up to 6,500 cu m of sediment per dam, and the wetted surface area of the channel is increased up to several hundred-fold. Beaver are also active in larger order streams, but their effects are most noticeable along riverbanks and in floodplains. Beaver ponds are important sites for organic matter processing; the stream metabolism index, a measure of ecosystem efficiency for the utilization or storage of organic inputs, is 1.63 for a pond on 2nd order Beaver Creek compared to 0.30 for the riffle upstream from it; the turnover length for particulate carbon is 1.2 km for the pond compared to 8.0 km for the riffle. Beaver-induced alterations to the structure and function of streams suggest that removal of beaver prior to 1900 had substantial effects on the dynamics of lotic ecosystems. It is suggested that current concepts of the organization and diversity of unaltered stream ecosystems in North America should recognize the keystone role of beaver, as drainage networks with beaver are substantially different in their biogeochemical economies than those without beaver.

Pinay, G. and R. J. Naiman. 1991.
Short-Term Hydrologic Variations and Nitrogen Dynamics In Beaver Created Meadows.
Archiv fur Hydrobiologie. 123:187-205.
Beaver (Castor canadensis) alter the structure and dynamics of aquatic ecosystems through their dam building and feeding activities. The environmental heterogeneity in beaver-created meadows and wetlands was assessed over distance, soil depth, and time in Voyageurs National Park, Minnesota. The influence of aerobic and anaerobic boundaries on nitrogen availability in beaver-created meadows was also investigated. Short-term fluctuations of the hydrological regime enhanced sediment nitrogen dynamics and nitrogen availability for plant growth in an otherwise impoverished boreal environment. These natural water level changes sustained beaver wetlands and meadows in a loose equilibrium where imposed deviations of the environmental conditions tended to remain within fixed upper and lower bounds, but did not appear to have preferred values. Such dynamical equilibrium in beaver-created meadows for aerobic-anaerobic status at the scale of a few meters sustained the structure and dynamics of sedge and grass vegetative patches occurring between pond and upland zones at the landscape scale. Similar patterns of nitrate availability occurred in the active pond and in the abandoned pond. This similarity between active and abandoned ponds suggests that environmental processes occurring during stream impoundment have a long term effect on sediment structure and functioning, affecting the pond long after it was drained.

Rosell, F., O. Bozs,r, P. Collen and H. Parker. 2005.
Ecological impact of beavers Castor fiber and Castor canadensis and their ability to modify ecosystems.
Mammal Review. 35:248-276.
1. The genus Castor comprises two species: the Eurasian beaver Castor fiber, and the North American beaver Castor canadensis. Both species suffered from overexploitation, but have seen a revival since the 1920s due to increased protection and reintroduction programmes. Increases in the populations and distributions of species that are able to modify ecosystems have generated

much scientific interest. Here we review the available literature concerning the possible ecological impact of beaver species in the Old and New World.2. Beavers, being ecosystem engineers, are among the few species besides humans that can significantly change the geomorphology, and consequently the hydrological characteristics and biotic properties of the landscape. In so doing, beavers increase heterogeneity, and habitat and species diversity at the landscape scale. Beaver foraging also has a considerable impact on the course of ecological succession, species composition and structure of plant communities, making them a good example of ecologically dominant species (e.g. keystone species).3. Nevertheless, the strength of beavers' impact varies from site to site, depending on the geographical location, relief and the impounded habitat type. Consequently, they may not be significant controlling agents of the ecosystem in all parts of their distribution, but have strong interactions only under certain circumstances. We suggest that beavers can create important management opportunities in the Holarctic, and this review will help land managers determine the likely outcome of beaver activity.

Syphard, A. D. and M. W. Garcia. 2001.
Human- and beaver-induced wetland changes in the Chickahominy River watershed from 1953 to 1994.
Wetlands. 21:342-353.
Historically, anthropogenic activities have contributed to the direct loss of wetland area, mostly due to agriculture and urban land uses. Urbanization also indirectly impacts wetlands at a landscape scale through altered wetland hydrology and change in the spatial configuration of wetlands in a watershed. In addition, beaver (Castor canadensis) create and modify wetlands in a landscape. Because of recent increases in urbanization and rising beaver populations, a raster-based geographic information system (GIS) was used to analyze the combined effects of humans and beavers on wetland area and types in the Chickahominy River watershed from 1953 to 1994. Results of the study revealed that 29% of the land changed during the 41-year study period, and wetland conversion constituted seven percent of the total change. The major reason for wetland loss was the construction of two large water-supply reservoirs in the watershed, and most of the remaining wetland loss was due to urbanization. Wetland functions vary depending on wetland type, and the results of this study showed that 90% of the change in wetlands from 1953 to 1994 was a result of shifting between wetland types. Beaver-modified wetlands increased 274%, and beaver activity was responsible for 23% of the wetland change.

Wohl, E. 2005.
Compromised Rivers: Understanding Historical Human Impacts on Rivers in the Context of Restoration.
Ecology & Society. 10:24-40 | 16.
A river that preserves a simplified and attractive form may nevertheless have lost function. Loss of function in these rivers can occur because hydrologic and geomorphic processes no longer create and maintain the habitat and natural disturbance regimes necessary for ecosystem integrity. Recognition of compromised river function is particularly important in the context of river restoration, in which the public perception of a river's condition often drives the decision to undertake restoration as well as the decision about what type of restoration should be attempted. Determining the degree to which a river has been altered from its reference condition requires a knowledge of historical land use and the associated effects on rivers. Rivers of the Front Range

of the Colorado Rocky Mountains in the United States are used to illustrate how historical land uses such as beaver trapping, placer mining, tie drives, flow regulation, and the construction of transportation corridors continue to affect contemporary river characteristics. Ignorance of regional land use and river history can lead to restoration that sets unrealistic goals because it is based on incorrect assumptions about a river's reference condition or about the influence of persistent land-use effects. (Author)

Wolf, E. C., D. J. Cooper and N. T. Hobbs. 2007.
Hydrologic regime and herbivory stabilize an alternative state in Yellowstone National Park.
Ecological Applications. 17:1572-1587 | 1572-87.
The article focuses in determining the relative influence of hydrologic regimes, as controlled by climate variation, beaver damming, and landscape changes, on the process of Yellowstone's northern range. The study was made with four streams on the northern range of Yellowstone National Park, USA. The four streams were selected because they have relatively large willow populations, have a riparian zone where groundwater is supported by streamflows, and lack significant hillslope groundwater inflows. Willow establishment data were compared to 20th century streamflow and precipitation data in detecting climatic influences on the timing of establishment. The reduced frequency of willow establishment during the 20th century is likely both a direct and indirect effect of elk browsing.

Woo, M.-K. and J. M. Waddington. 1990.
Effects of beaver dams on subarctic wetland hydrology.
Arctic. 43:223-230.

Wright, J. P., A. S. Flecker and C. G. Jones. 2003.
Local vs. landscape controls on plant species richness in beaver meadows.
Ecology. 84:3162-3173.
There is considerable interest in determining whether the species richness of communities is determined by forces controlling dispersal into patches that operate at the landscape scale, or forces controlling persistence that act at the local scale. Understanding the relative importance of these two classes of factors in controlling within-patch species richness is particularly important when patches are created via ecosystem engineering. In such cases, factors affecting the population dynamics or behavior of a single species could indirectly affect species richness if richness is controlled primarily by landscape-level factors. We used a combination of experimental mesocosms and field observations to determine whether species richness in beaver wetlands in the Adirondack Mountains (New York) is more strongly controlled by the position of the wetland in the landscape or by within-wetland hydrology. Drainage rate had a significant effect on both richness and composition in mesocosms, with well-drained treatments having significantly higher richness than poorly drained treatments. Seed germinated from the seed bank in sediments collected from different ponds showed relatively small differences in richness or community composition in mesocosms, suggesting a comparatively small effect of dispersal limitation on species richness. Experimental results were mirrored in a survey of 14 meadows over two years, which indicated that variability in water table depth was consistently a significant predictor of species richness, while meadow area and isolation showed little relation to richness. The survey also suggested that the number of years since beaver had abandoned a site was a significant predictor of the number of species found in beaver meadows. The results

indicate that species richness in beaver meadows is strongly controlled by local factors, but that the population dynamics of beaver could also potentially affect species richness by altering the age distribution of meadows across the landscape.

Zeigenfuss, L. C., F. J. Singer, S. A. Williams and T. L. Johnson. 2002.
Influences of herbivory and water on willow in elk winter range.
Journal of Wildlife Management. 66:788-795 | 788.
Elimination of large predators and reduced hunter harvest have led to concerns that an increasing elk (Cervus elaphus) population may be adversely affecting vegetation on the low-elevation elk winter range of Rocky Mountain National Park, Colorado, USA. Beaver (Castor canadensis) and their impoundments also have declined dramatically (94%) in the same area over the past 50 years coincident with a 20% decline in willow (Salix spp.) cover. From 1994 to 1998, we studied vegetation production responses of willow communities to elk herbivory and water availability. We estimated willow production by measuring current annual growth of shrubs in 9.3-m2 circular plots, and we measured herbaceous production by clipping vegetation within 0.25-m2 circular plots. Elk herbivory suppressed willow heights, leader lengths, annual production, and herbaceous productivity of willow communities. Water impoundment had a positive effect on herbaceous plant production, but little effect on shrubs, possibly because water tables were naturally high on the study sites even without beaver dams. Nevertheless, the winter range environment previously included more riparian willow habitat because of more stream area (47-69%) due to larger beaver populations. Elk herbivory appears to be the dominant force determining vegetation productivity in willow sites, but the effects may be exacerbated by lowered water tables. Fewer elk or protection from browsing, and water enhancement for <10 years along with management to encourage elk movement away from willow communities, could possibly work as strategies to reestablish sustainable willow communities.

Interspecific interactions and relationships

Adams, A. K. 1954.
Some physico-chemical effects of beaver dams upon Michigan trout streams in the Watersmeet area.
University of Michigan.

Detailed study of water temperatures, oxygen content, and other factors affecting trout in and near beaver impoundments. Comparisons are made with streams that lacked dams. "The chemical conditions in the impoundments unsatisfactory for brook trout seem to encourage competitive fishes such as creek chubs and white suckers to become dominant. Native brook trout proved surprisingly resistant to temperatures above 80°F. for short periods of time in field experiments... The heating of tributaries was more consequential down-stream than in the ponds themselves..." "...discouragement or removal of beaver on marginal trout waters may be warranted when stream survey procedures include an appraisal of beaver-trout relationships."

Baker, J. L. 1966.
The renovation of beaver ponds for the production of duck food.
Mississippi State University.

Ballou, R. M. 1950.
Wildlife activity on beaver ponds in Jackson Hole.
University of Michigan.

Barnes, D. M. 1997.
Beaver dams: their site selection, establishment, and impact in a northern Ontario watershed.

Bates, J. W. 1963.
Effects of beaver on stream flow.
Utah State University.

Bradley, P. V. 1986.
Ecology of river otters in Nevada.
University of Nevada.

Bullock, J. F., Jr. 1982.
The ecological and economic impact of beaver (Castor canadensis) on bottomland forest ecosystems of Mississippi.
Mississippi State University.

Buttram, J. R. 1959.
Arthopod commensals found in the nest of the beaver, Castor carolinensis (Rhoades).
Mississippi State University.

Call, M. W. 1970.
Beaver pond ecology and beaver-trout relationships in southeastern Wyoming.
University of Wyoming.

Casagranda, L. G. 1955.
A study of beaver-waterfowl relations in the mountainous area of Beaverhead County, Montana.
Montana State University.

Cottrell, T. R. 1995.
Willow colonization of Rocky Mountain mires.
Canadian Journal of Forest Research. 25:215-222.
<i>Salix planifolia</i> subsp. <i>planifolia</i> and <i>Salix monticola</i> are the dominant willow species of Colorado Rocky Mountain willow carrs. Extensive field observations suggest that neither of these species is capable of sexual propagation under continuous sedge cover on peat soils. Growth experiments using willow stem cuttings in pots of saturated peat soil indicate that <i>S. planifolia</i> produces more root biomass and shoot biomass than <i>S. monticola</i> during one summer of growth. Male <i>S. planifolia</i> and female <i>S. monticola</i> produce more dry-weight root and shoot biomass than their conspecific opposite sex. A species by sex by elevation interaction is significant for root biomass. The results suggest that these taxa have different regeneration niches. Asexual propagation driven by beaver [<i>Castor canadensis</i>] activity is suggested as an explanation for the dominance of <i>S. planifolia</i> in mires and how this species colonizes vegetated peat soils. Beaver cut and store

willow stems for a winter food source. This activity provides willow fragments for asexual colonization of mires.

Elmqvist, T., R. G. Cates, J. K. Harper and H. Gardfjell. 1991.
Flowering in males and females of a Utah willow, *Salix rigida* and effects on growth, tannins, phenolic glycosides and sugars.
Oikos. 61:65-72.
Resource allocation to reproduction in male and female <i>Salix rigida </i>in a population in Utah was manipulated by removing reproductive buds before expansion, and female flowers before fruit initiation. Fruiting females produced smaller shoots, fewer reproductive buds and had lower concentrations of salicortin and tannins than females in the flower-removal treatment. No effect of treatment on growth or secondary metabolites was detected in males. Female controls produced less shoot biomass and fewer reproductive buds than male controls, suggesting that total reproductive effort is greater and reproduction more resource-limited in females than in males. Female willows had higher concentrations of tannin (reproductive and basal shoots) and salicortin (reproductive buds and shoots, and basal shoots). Differences of this type could be the proximate mechanism behind the common pattern of more vertebrate herbivory in males than in females. Beaver (<i>Castor canadensis</i>) is an important vertebrate herbivore on <i>S. rigida </i>in the study area. This study supports the assumption that allocation to reproduction during one season may reduce growth and future reproductive potential. In addition, fruiting reduces concentrations of secondary metabolites, some of which may be effective as defenses against vertebrate herbivores.

Faaborg, R. 1981.
Effects of moose grazing on sodium cycling and aquatic macrophyte communities in beaver ponds.
University of Minnesota.

Gard, R. 1958.
The effects of beaver dams on trout in Sagehen Creek, California.
University of California.

Ingram, J. W. 1997.
The effect of flooding duration on productivity of beaver ponds in eastern Ontario.

Johns, B. A. 1958.
A distribution of the beaver in Florida and a study of its ecology in the Flint-Chattahoochee-Apalachicola region.
University of Florida.

Johnson, R. C. 1976.
An evaluation of 2, 4-D amine and fire to control pest plants occurring in a beaver pond managed for waterfowl in Macon County, Alabama.
43:Auburn University.

Kafka, D. M. 1988.

Use of beaver-influenced wetlands by waterfowl on the Kanuti National Wildlife Refuge.
111:University of Alaska.

Keiper, R. R. 1966.
The distribution and faunal succession of the macroscopic bottom fauna in three different aged beaver ponds.
96. University of Massachusetts.

Kirby, R. E. 1973.
Utilization of beaver flowages by waterfowl on the Chippewa National Forest, Minnesota.
264:Southern Illinois University.

Lancia, R. A. 1979.
Year-long activity patterns of radio-marked beaver (Castor canadensis).
161:5678. University of Massachusetts.

DISSERTATION (PH.D.) - UNIVERSITY OF MASSACHUSETTS. APPENDIX I - KETAMINE HYDROCHLORIDE AS AN IMMOBILANT AND ANAESTHETIC FOR BEAVER. J. WILDL. MANAGE. 92(3): 946-948. APPENDIX II - A TELEMETRY SYSTEM FOR CONTINUOUSLY RECORDING LODGE USE, NOCTURNAL AND SUBNIVEAN ACTIVITY OF BEAVER (CASTOR CANADENSIS)

McCollum, R. C. 1992.
Comparative use of lower, headwater, and beaver-impacted floodplains by swamp rabbits.
59:Auburn University.

McGinley, M. A. and T. G. Whitham. 1985.
Central place foraging by beavers (Castor canadensis): A test of foraging predictions and the impact of selective feeding on the growth form of cottonwoods (Populus fremontii).
Oecologia. 66:558-562.
Several predictions of central place foraging theory were tested at a site in Utah, USA, by recording numbers of cut and uncut branches of trees at distances from 3.5 to 73 m from the river's edge. With increasing distance from the river's edge, beavers cut fewer branches and excluded small branches from their diet. Large branches were favoured at all distances. High rates of branch removal caused <i>P. fremontii </i>to develop a shrubby architecture. The effect of selective harvesting of branches by beavers on patterns of <i>P. fremontii </i>reproduction (delayed sexual maturity and induced cloning) is discussed.

Neff, D. J. 1956.
Ecological effects of habitat abandonment by beavers on a high mountain valley in Colorado.
Colorado State University.

Nevers, H. P. 1968.
Waterfowl utilization of beaver ponds in southeastern New Hampshire.
University of New Hampshire.

Payne, F. J. 1961.
Effects of beaver flooding of alder woodcock habitat on the Moosehorn National Wildlife Refuge.
University of Maine.

Pfeiffer, E. W. 1948.
Some factors affecting the winter ranges of Jasper National Park.
University of British Columbia.

Preacher, J. W. 1975.
An evaluation of duck food plants produced in beaver ponds in Macon County, Alabama.
Auburn University.

Pullen Jr., T. M. 1971.
Some effects of beaver (Castor canadensis) and beaver pond management on the ecology and utilization of fish populations along warm-water streams in Georgia and South Carolina.
University of Georgia.

Reese, K. P. 1976.
Avian community structure of beaver pond, hardwood, and pine habitats in the Piedmont region of South Carolina.
Clemson University.

Reid, D. G. 1984.
Ecological interactions of river otters and beavers in a boreal ecosystem.
University of Calgary.

Rudersdorf, W. J. 1953.
The co-actions of beaver and moose on joint food supply in the Buffalo River meadows and surrounding area in Jackson Hole, Wyoming.
Utah State University.

Rudersdorf, W. J. 1954.
The co-action of beaver and moose on a joint food supply in the Buffalo River meadows and surrounding area in Jackson Hole, Wyoming.
Utah State University.

Rutherford, W. H. 1954.
Interrelationships of beavers and other wildlife on a high-altitude stream in Colorado.
Colorado State University.

Sanner, C. J. 1987.
Effects of beaver on stream channels and Coho salmon habitat, Kenai Peninsula, Alaska.
Department of Fisheries and Wildlife. 81:Oregon State University.

Shelton, P. C. 1966.

Ecological studies of beavers, wolves, and moose in Isle Royale National Park, Michigan.
Purdue University.

In 1900 none of the 3 spp. studied was known to be present on the island. No effective moose predators were present and no hunting was allowed. Moose increased to 2,000 to 3,000 by 1930 and they denuded much of the island of its shrubby vegetation. Food shortage caused repeated die-offs from then until about 1948, when timber wolves crossed from Canada and began harvesting moose. Studies made during 1958-1961 showed that at least 600 moose and 20 wolves inhabited the island and that high annual productivity of moose was approximately balanced by loss to predation. Recovery of moose browse species was noticeable. Continued observations during the present study (1960-1963) showed no essential change in wolf-moose relationships. Beavers increased to an estimated 500 to 600 by 1930, and a peak population of 1,000 to 1,300 reached in the late 1940's was followed by a decline, which was then thought to be caused by food shortage. Evidence from this study, including the presence of adequate food supplies at active and abandoned sites, and the increase in beavers since the decline, indicated that food shortage did not cause the decrease. Epizootic tularemia, then widespread in the Great Lakes Region, may have been responsible.

Smith, A. E. 1950.
Effects of water run-off and gradient on beaver in mountain streams.
University of Michigan.

Stanton, P. B. 1965.
An evaluation of waterfowl utilization on three age classes of beaver impoundments with emphasis on the black duck (*Anas rubripes*).
112. University of Massachusetts.

Sverre, S. F. S. 1972.
Some ecological effects of beaver upon the watersheds in Porcupine Hills, Alberta.
Brock University.

Swimley, T. J., R. P. Brooks and T. L. Serfass. 1999.
Otter and beaver interactions in the Delaware Water Gap National Recreation Area.
Pennsylvania Academy of Science. Journal. 72:97-101.
Beaver populations have expanded throughout the Northeast and Mid-Atlantic states in recent years. This population expansion has resulted in an increase in complaints related to habitat modifications by beavers. Fur trapping has been the preferred management tool for beaver; however, there can be substantial incidental captures and deaths of non-target species, especially river otters. The authors conducted surveys of 65 riparian habitat reaches along 64 km of streams and ponds in the Delaware Water Gap National Recreation Area (DWGNRA) from April-July, 1998 to assess the current locations of beaver colonies, and determine how otters and beavers interacted in various riparian habitats. During ground surveys, they located 27 active and 45 inactive beaver lodges and 61 otter latrines. Thirty-four (52%) survey reaches contained active or inactive beaver habitats and 71% of survey reaches with active or inactive beaver sign showed evidence of otter use. Fifty-eight (95%) otter latrines were associated with survey reaches currently or previously occupied by beavers. There was a significant positive

relationship between presence of beaver activity (active or abandoned) within a survey reach, and otter use (X²=24.8, P<0.001). Many otter latrines (34%) were within 50 m of active or inactive beaver lodges. Eighty-one percent of active beaver lodges and 85% of otter latrines were located in lake- or pond-dominated survey reaches and low-gradient stream sections. Beaver activity was uncommon in high-gradient habitats, and otter latrines were uncommon in non-beaver habitats. A management program that targets specific beaver colonies and includes the use of snares, padded leg-hold traps, firearms, and professionally trained personnel will minimize impacts on otters. Additional use of water level control devices is preferred over lethal means, whenever possible.

Wesley, D. E. 1967.
An ecological comparison of beaver ponds and farm ponds, with emphasis on productivity of invertebrates and fish.
Mississippi State University.

Wilkinson, R. N. 1988.
A habitat evaluation and management plan for a riparian ecosystem.
University of North Texas.

Management

Allred, M. 1981.
The potential use of beaver population behavior in beaver resource management.
Idaho Academy of Science. 17:14-24.

Askins, R. A., F. Ch vez-Ram¡rez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf and P. D. Vickery. 2007.
Conservation of grassland birds in North America: understanding ecological processes in different regions: report of the AOU committee on conservation.
Ornithological Monographs. 64:1-46.
[unedited] Many species of birds that depend on grassland or savanna habitats have shown substantial overall population declines in North America. To understand the causes of these declines, we examined the habitat requirements of birds in six types of grassland in different regions of the continent. Open habitats were originally maintained by ecological drivers (continual and pervasive ecological processes) such as drought, grazing, and fire in tallgrass prairie, mixed-grass prairie, shortgrass prairie, desert grassland, and longleaf pine savanna. By contrast, grasslands were created by occasional disturbances (e.g., fires or beaver [Castor canadensis] activity) in much of northeastern North America. The relative importance of particular drivers or disturbances differed among regions. Keystone mammal species-grazers such as prairie-dogs (Cynomys spp.) and bison (Bison bison) in western prairies, and dam-building beavers in eastern deciduous forests-played a crucial, and frequently unappreciated, role in maintaining many grassland systems. Although fire was important in preventing invasion of woody plants in the tallgrass and moist mixed prairies, grazing played a more important role in maintaining the typical grassland vegetation of shortgrass prairies and desert grasslands. Heavy grazing by prairie- dogs or bison created a low "grazing lawn" that is the preferred habitat for many grassland bird species that are restricted to the shortgrass prairie and desert grasslands.

Ultimately, many species of grassland birds are vulnerable because people destroyed their breeding, migratory, and wintering habitat, either directly by converting it to farmland and building lots, or indirectly by modifying grazing patterns, suppressing fires, or interfering with other ecological processes that originally sustained open grassland. Understanding the ecological processes that originally maintained grassland systems is critically important for efforts to improve, restore, or create habitat for grassland birds and other grassland organisms. Consequently, preservation of large areas of natural or seminatural grassland, where these processes can be studied and core populations of grassland birds can flourish, should be a high priority. However, some grassland birds now primarily depend on artificial habitats that are managed to maximize production of livestock, timber, or other products. With a sound understanding of the habitat requirements of grassland birds and the processes that originally shaped their habitats, it should be possible to manage populations sustainably on "working land" such as cattle ranches, farms, and pine plantations. Proper management of private land will be critical for preserving adequate breeding, migratory, and winter habitat for grassland and savanna species.

Baker, B. W. 2003.
Beaver (Castor canadensis) in heavily browsed environments.
Lutra. 46:173-181.
Beaver (Castor canadensis) populations have declined or failed to recover in heavily browsed environments. I suggest that intense browsing by livestock or ungulates can disrupt beaver-willow (Salix spp.) mutualisms that likely evolved under relatively low herbivory in a more predator-rich environment, and that this interaction may explain beaver and willow declines. Field experiments in Rocky Mountain National Park, Colorado, USA, found the interaction of beaver and elk (Cervus elaphus) herbivory suppressed compensatory growth in willow. Intense elk browsing of simulated beaver-cut willow produced plants which were small and hedged with a high percentage of dead stems, whereas protected plants were large and highly branched with a low percentage of dead stems. Evaluation of a winter food cache showed beaver had selected woody stems with a lower percentage of leaders browsed by elk. A lack of willow stems suitable as winter beaver food may cause beaver populations to decline, creating a negative feedback mechanism for beaver and willow. In contrast, if browsing by livestock or ungulates can be controlled, and beaver can disperse from a nearby source population, then beaver may build dams in marginal habitat which will benefit willow and cause a positive riparian response that restores proper function to degraded habitat. In a shrub-steppe riparian ecosystem of northwestern Colorado, USA, rest from overgrazing of livestock released herbaceous vegetation initiating restoration of a beaver-willow community. Thus, competition from livestock or ungulates can cause beaver and willow to decline and can prevent their restoration in heavily browsed riparian environments, but beaver and willow populations can recover under proper grazing management.

Bradt, G. W. 1947.
Michigan beaver management.

In 6 chapters the author discusses "History", "General Characteristics", "Population Studies", "Management", "Beaver Farming", and "Beaver vs. Trout Controversy." The chapter on population studies describes research methods, life history, behavior, and food. Management

requires a method of censusing; measures of reproductive rate, mortality factors, and food supply; knowledge of the manner of dispersal; and means and authority for controlling the harvest by man. There are excellent, large photos and entertaining drawings.

Breck, S. W., K. R. Wilson and D. C. Andersen. 2001.
The demographic response of bank-dwelling beavers to flow regulation: a comparison on the Green and Yampa rivers.
Canadian Journal of Zoology. 79:1957-1964.
The authors assessed the effects of flow regulation on the demography of beavers (Castor canadensis) by comparing the density, home-range size, and body size of bank-dwelling beavers on two sixth-order alluvial river systems, the flow-regulated Green River and the free-flowing Yampa River, from 1997 to 2000. Flow regulation on the Green River has altered fluvial geomorphic processes, influencing the availability of willow and cottonwood, which, in turn, has influenced the demography of beavers. Beaver density was higher on the Green River (0.5-0.6 colonies per kilometre of river) than on the Yampa River (0.35 colonies per kilometre of river). Adult and subadult beavers on the Green River were in better condition, as indicated by larger body mass and tail size. There was no detectable difference in home range size, though there were areas on the Yampa River that no beavers used. The authors attribute the improved habitat quality on the Green River to a greater availability of willow. They suggest that the sandy flats and sandbars that form during base flows and the ice cover that forms over winter on the Yampa River increase the energy expended by the beavers to obtain food and increase predation risk and thus lowers the availability of woody forage.

Buckley, J. L. 1955.
The ecology and economics of the beaver (*Castor canadensis*, Kuhl) with a plan for its management on the Huntington Wildlife Forest Station.
Syracuse University.

Bump, G. 1941.
Problems of beaver management in a fish and game program.
300-306.
Beavers, once greatly reduced, increased as a result of protection and plantings and caused many complaints of damage. The State of New York tried control by paid trappers and by allowing complainants to dynamite dams, and shoot or trap the animals under permits. The second method proved more economical and more satisfactory. Experience with both systems is sketched and the injuries and benefits associated with beavers are listed. "To sum up, the successful introduction of beavers into a favorable environment inevitably engenders a host of problems. These arise from, or are affected by, the value of the resultant fur crop, the deep public interest in beavers, the probability that some of the beavers will become a nuisance, the impracticability of handling this problem through continued removal of beavers by state trappers, the necessity of developing more satisfactory methods of control, and the pulling and hauling of divergent interests that are affected variously by an increase in beaver abundance and activities. These matters should be carefully analyzed and their effects weighed before the species is introduced. "Some one has defined a wood as merely a plant out of place. Even beavers can be in this category unless they are properly managed." Bibliography of 7 titles.

Byford, J. L. 1974.
Beavers in Tennessee: Control, utilization and management.

Conn, H. R. 1951.
Federal aid in fur-resources management in Canada.
437-443.
An account of successful management of beaver and muskrats in Manitoba, Saskatchewan, Ontario, and Quebec, beginning in 1936.

Connelly, N. A., D. J. Decker and K. G. Purdy. 1989.
Dispersal of Trappers to Engage in Beaver Trapping in Northern New York.
Transactions of the Northeast Section of the Wildlife Society. 46:32-40.
Insights were obtained about the degree to which trappers will travel from the management area where they reside to other areas.

Connelly, N. A., D. J. Decker and K. G. Purdy. 1989.
Trapping Season Preferences of Beaver Trappers in Northern New York.
Transactions of the Northeast Section of the Wildlife Society. 46:41-52.

Couch, L. K. 1942.
Trapping and transplanting live beavers.
U.S. Department of the Interior. Conservation Bulletins. 30:20.
Supersedes U. S. Dept. of Agriculture Farmers' Bulletin 1768. Treats beavers in relation to soil and water conservation and to fur animals and fishes; losses to agriculture caused by beavers; trapping, transporting, and planting the animals; and the beaver as an asset in rural sections.

Cunningham, J. M., A. J. K. Calhoun and W. E. Glanz. 2007.
Pond-breeding amphibian species richness and habitat selection in a beaver-modified landscape.
Journal of Wildlife Management. 71:2517-2526.
Beaver (Castor canadensis) activity creates wetland habitats with varying hydroperiods important in maintaining habitat diversity for pond-breeding amphibians with significantly different breeding habitat requirements. We documented pond-breeding amphibian assemblages in 71 freshwater wetlands in Acadia National Park, Maine, USA. Using 15 variables describing local pond conditions and wetland landscape characteristics, we developed a priori models to predict sites with high amphibian species richness and used model selection with Akaike's Information Criterion to judge the strength of evidence supporting each model. We developed single-species models to predict wood frog (Rana sylvatica), bullfrog (R. catesbeiana), and pickerel frog (R. palustris) breeding site selection. Sites with high species richness were best predicted by 1) connectivity of wetlands in the landscape through stream corridors and 2) wetland modification by beaver. Wood frog breeding habitat was best predicted by temporary hydroperiod, lack of fish, and absence of current beaver activity. Wood frog breeding was present in abandoned beaver wetlands nearly as often as in nonbeaver wetlands. Bullfrog breeding was limited to active beaver wetlands with fish and permanent water. Pickerel frog breeding sites were best predicted by connectivity through stream corridors within the landscape. As beavers have recolonized areas of their former range in North America, they have increased the number and diversity of available breeding sites in the landscape for pond-breeding amphibians. The

resulting mosaic of active and abandoned beaver wetlands both supports rich amphibian assemblages and provides suitable breeding habitat for species with differing habitat requirements. Land managers should consider the potential benefits of minimal management of beavers in promoting and conserving amphibian and wetland diversity at a landscape scale. (Author)

Denney, R. N. 1952.
A summary of North American beaver management, 1946-1948.
28:
The first part of this paper is based on survey of literature and questionnaire returns from states and provinces. Major headings are: life history and habitat trends, populations, ecological effects (includes damage and relationships with trout), farms and refuges, trapping seasons and limits, size and value of harvest, and law enforcement problems. The second part of the paper presents results of a live-trapping study in Colorado: fate of marked beavers, travels, sex ratio, weights, experimental transplanting by parachute. The paper should be a valuable source of many types of information on beavers, particularly because of the large amount of data from so many political units. 58 references.

Denny, R. N. 1951.
A program for administration and management of the beaver in Colorado.

Destefano, S. and R. Deblinger. 2005.
Wildlife as valuable natural resources vs. intolerable pests: a suburban wildlife management model.
Urban Ecosystems. 8:179-190.
Management of wildlife in suburban environments involves a complex set of interactions between both human and wildlife populations. Managers need additional tools, such as models, that can help them assess the status of wildlife populations, devise and apply management programs, and convey this information to other professionals and the public. We present a model that conceptualizes how some wildlife populations can fluctuate between extremely low (rare, threatened, or endangered status) and extremely high (overabundant) numbers over time. Changes in wildlife abundance can induce changes in human perceptions, which continually redefine species as a valuable resource to be protected versus a pest to be controlled. Management programs thatincorporate a number of approaches and promote more stable populations of wildlife avoid the problems of the resource versus pest transformation, are less costly to society, and encourage more positive and less negative interactions between humans and wildlife. We presenta case example of the beaver Castor canadensis in Massachusetts to illustrate how this model functions and can be applied. (Author)

Dickinson, N. R. 1971.
Aerial photography as an aid in beaver management.
New York Fish and Game Journal. 18:57-61.

Dolbeer, R. A. 1998.
Population dynamics: the foundation of wildlife damage management for the 21st century.
Proceedings 18th Vertebrate Pest Conference

("Proceedings of the Eighteenth Vertebrate Pest Conference held March 2-5, 1998 in Costa Mesa, California" Editors: Baker, Rex O.; Crabb, A. Charles). 2-11.
The author describes four population models (PM1 to PM4) for predicting population responses. PM1 and PM2 explore the relative efficacy of reproductive and lethal control for vertebrate species over 10-year intervals. PM3 simulates population responses to actual management actions through 10-year intervals. PM4 simulates population changes for a species at weekly intervals over an annual cycle, exploring the immediate impact of population management actions. Population simulations using PM1 and PM2 demonstrated that for most vertebrate pest species considered, lethal control will be more effective than reproductive control. A simulation (PM3) of the removal of 47,000 laughing gulls from the Long Island-New Jersey population accurately predicted the 33 percent decline of the population over five years. klf.

Enck, J. W. and T. L. Brown. 1996.
Citizen participation approaches for successful beaver management.
Human Dimensions of Wildlife. 1:78-79.
Wildlife managers in New York believe that new approaches are needed for encouraging and including public input into beaver management decisions. Successful citizen participation would allow stakeholders to help develop the decision-making process as well as review and comment on the decision. pcp.

Enck, J. W., N. A. Connelly and T. L. Brown. 1996.
Public Attitudes Toward Wildlife and Its Accessibility. Public Attitudes Toward Beaver and Beaver Management: Management Response to Beaver Complaints in WMU 21.
New York [State]. Department of Environmental Conservation. Annual Report. 1996:44.
Information is synthesized from a reanalysis of three previous studies of stakeholder's (general public, landowners, and highway superintendents) beaver-related attitudes and experiences in New York (Purdy and Decker 1985, Enck et al. 1988, Enck et al. 1992). Regression models were developed to predict acceptance of beavers and acceptance of actions to address nuisance beaver problems.

Enck, J. W., N. A. Connelly and T. L. Brown. 1997.
Acceptance of beaver and actions to address nuisance beaver problems in New York.
Human Dimensions of Wildlife. 2:60-61.
The authors developed regression models predicting acceptance of beaver and acceptance of actions to address nuisance beaver problems using data from three mail surveys conducted in New York from 1985-1992. klf.

Ermer, E. M. 1982.
A cost/benefit analysis approach to beaver population management.
Transactions of the Northeast Section of the Wildlife Society. 39:18.

Ermer, E. M. 1984.
Analysis of benefits and management costs associated with beaver in western New York.
New York Fish and Game Journal. 31:119-132.

Fitzgerald, W. S. and R. A. Thompson. 1988.

Problems associated with beaver in stream or floodway management.
Proc. 13th Vertebrate Pest Conf.
Vertebrate Pest Conference. Proceedings. 13:190-195.

Grasse, J. E. 1949.
Beaver trapping and transplanting.
Wyoming Wildlife. 13:10-17, 34.
The author describes techniques and experiences in Wyoming. "It is planned that during the 1949 livetrapping season we will retrap as many beaver as possible which were planted in 1947 and 1948, so that accurate growth and development studies can be made."

Grasse, J. E. and E. F. Putnam. 1950.
Beaver management and ecology in Wyoming.
58.
This bulletin has chapters on beaver history, physical characteristics, life history, ecology and management, trapping and transplanting, and post-planting studies. It has many large, clear photos.

Grasse, J. E. 1951.
Beaver ecology and management in the Rockies.
Journal of Forestry. 49:3-6.

Grasse, J. E. 1952.
Beaver ecology and management in the Rockies.
Wyoming Wildlife. 16:26-34.
Reprinted from the January 1951 issue of The Journal of Forestry. The bulk of the paper treats the value of beavers in watershed and wildlife protection. Beaver work in the West generally favors trout. In the Rocky Mountain region the value of beaver work is so great that no open season should be considered. Nuisance beavers on private land can continue to be taken on fur-farm or damage permits as they now are.

Grasse, J. E. and E. F. Putnam. 1955.
Beaver management and ecology in Wyoming.

Hadidian, J. 2003.
Managing conflicts with beaver in the United States: an animal welfare perspective.
Lutra. 46:217-222.
As had happened earlier in Europe, the American beaver (Castor canadensis) was almost completely extirpated from its historic range because of human exploitation. Anywhere from 50 to 400 million beaver may have occurred throughout North America prior to the arrival of Europeans. Today, the population in the United States has recovered from unknown historic lows to a point where conflicts with humans have notably increased. The standard approach to resolving human-beaver conflicts has been to kill beaver and destroy their structures. From both an environmental as well as animal welfare perspective this approach is regarded as short-sighted. This paper addresses the issue of humane and environmentally responsible beaver conflict management, and identifies alternatives that control the problems beaver cause without

necessitating their removal. It also addresses the benefits created by the presence of beaver in even highly urbanized ecosystems and details the strategy of one animal protection organization, the Humane Society of the United States, to educate the public about the beneficial role these animals can play.

Hammerson, G. A. 1994.
Beaver (*Castor canadensis*): Ecosystem alterations, management, and monitoring.
Natural Areas Journal. 14:44-57.

Harris, D. and S. E. Aldous. 1946.
Beaver management in the northern Black Hills of South Dakota.
Journal of Wildlife Management. 10:348-353.
History of beavers in the region and of early and present-day trapping. Once nearly exterminated, the animals have been restored by transplanting to prepared sites and by well-planned management. These operations are described. A live trap is illustrated and trapping for fur under State control is described.

Hatch, A. B. 1943.
The wartime status of beaver in the western United States.
302-307.
Although beaver restoration has had very satisfactory results, the presence of the animals in abundance has inspired attempts to get legislation that will permit their exploitation. The author points out the dangers involved and proposes a system of beaver administration and management to maintain the species as a permanent resource.

Hensley, A. L. 1946.
A progress report on beaver management in California.
California Fish and Game. 32:87-99. CAL. DEPT. OF FISH AND GAME.

The history of fur exploitation and legislation affecting beavers in California is reviewed and investigations and transplanting experiments are reported upon. Management problems are discussed. With a good plan and caution, the author believes that a management program beneficial to all concerned can be worked out in the State.

Hensley, A. L. and B. C. Fox. 1948.
Experiments on the management of Colorado River beaver.
California Fish and Game. 115 | 34:15-131 | 115-131. California Department of Fish and Game.

The authors report on the study which California and Arizona made during the period 1943-1947. Surveys to determine density of population and to evaluate the effects of cropping were made each year along the portion of the river between the two states. It was found that "Harvesting beaver on a per pelt basis proved more satisfactory than on a basis of salaried trappers. Equipment purchased by the states made it possible to maintain a higher efficiency in the trapping activity by reducing the loss in trapped animals and damage to pelts. Systematic trapping requires close supervision or the animals will not be cropped to the best advantage or in the predetermined numbers." "The fact that this program has been more than self sustaining, yielding a substantial profit credited to the participating states, justifies continuance of the management study."--M. Alberts.

Highby, P. R. 1940.
The story of Minnesota beaver.
The Conservation Volunteer. 1:41-46.
By the year 1900 beavers had been trapped almost to the vanishing point. Re-introduced in Itasca Park in 1901, the initial population of 3 (1 {female}, 2 {male}) had increased by 1907 by some 300 in the Park and had spread to other sections. In 1939 an open season was declared and more than 11,000 pelts were taken. The return to trappers was in excess of $120,000. Conservative management is all that is needed to retain the beaver as a continuing asset. The animals' habits are described, and the problems they cause by flooding areas man desires for other purposes, their relation to trout streams and flood control, and the good they do in creating ponds and meadows also are discussed.

Hodgdon, K. W. and J. H. Hunt. 1953.
Beaver management in Maine.

Detailed paper based on work of several men since 1946. It should be seen by anyone concerned with beaver management. Much of the biological information cannot be mentioned in a brief review. Among major topics are history in state, weights and measurements, life history, ecological relations to other animals, economics, and management recommendations. Some of the graphs show (usually by age groups): incisor width, skinned weights, tail area, hind foot length, furred length, total length, breeding dates calculated from embryo weights, growth of young, and size groups of pelts. Predation on beaver was insignificant. Parasitism (reported quantitatively) was common but seemed to be of no population importance. Effect of beaver on other game was beneficial. Effect on trout was often beneficial, sometimes harmful. Effect on valuable timber was slight, and most big timber owners favor present beaver populations, partly because they aid fire control. Beaver populations and carrying capacity were determined for each township of state; management will be based partly on these figures. Trapping season should be in March, after mating season. Trapping should be regulated by township or stream, with closure when necessary, and with length of season set for state by game commission. Beaver farming was found to be unprofitable.

Hood, G. A. and S. E. Bayley. 2003.
Fire and beaver in the boreal forest-grassland transition off western Canada - A case study from Elk Island National Park, Canada.
Lutra. 46:235-241.
Prescribed fire is used as a management tool in many areas throughout the world to restore vegetation communities, reduce fuel loading, and enhance wildlife habitats. However, the effect of prescribed fire on many wildlife species has not been well studied, especially on beavers (Castor canadensis). The purpose of our study was to examine whether prescribed fire influences beaver lodge occupancy in the aspen and mixed-wood habitats of Elk Island National Park, Alberta, Canada. In particular, we examined whether lodges in burned habitats experience lower occupancy levels than lodges in unburned habitats, whether the frequency of burns influences

lodge abandonment, and whether the distance to suitable habitat potentially accessible from those lodges abandoned following a burn, influence beaver lodge occupancy. Since 1979, over 51% of Elk Island National Park (196 km2) has been burned with the goal of restoring prairie plant communities. We found that fire negatively affected beaver lodge occupancy, an effect compounded with frequent burns. Though prescribed fire is considered an important landscape restoration process, the frequency of prescribed burning should be mitigated to ensure that flooding by beavers can continue as a key process that maintains wetlands on the landscape.

Howard, R. J. and J. S. Larson. 1985.
A stream habitat classification system for beaver.
Journal of Wildlife Management. 49:19-25.

Huey, W. S. 1956.
New Mexico beaver management.

Useful, informative, well illustrated bulletin. Practically all suitable habitat in N. M. now has beaver. Population in state is about 7,000. Public harvest was 305 in 1953 (when season was opened), 405 in 1954. Peak of pelt primeness extends Jan.-Mar. Beaver waters have far more and slightly larger trout than have comparable non-beaver waters. A good study on this is reported. Of beaver repellents tested, best is 10% trinitrobenzine-aniline in acetone with arachlors; it gave trees reasonable protection for 3-4 months. Structures of concrete, pipe, and fencing that were developed are 80-90% effective in preventing travel up and down stream but permit debris to pass through. Long, perforate, fiber pipes run through dams are good regulators of pond levels. To judge from statistical analysis of 36 sets of embryos, av. litter size is 4.2 in aspen areas, 2.75 in cottonwood areas, and 2.06 from overused habitats. Willows were planted along a stream that lacked beaver and beaver foods. Survival was about 25% despite some browsing by cattle. "These results indicate that under normal use by livestock it may be estimated that in five to ten years this type of development will support an introduction of beavers." Other topics taken up include: history of beaver in state, size and management status of local populations, pelt prices 1938-55, results of opening season for public trapping, and instructions for pelting and trapping.

Huey, W. S. 1956.
Management of furbearing animals: Effects of habitat on beaver productivity.

Jackson, A. W. 1953.
Beaver resources management survey: Development of a method of beaver range evaluation.

Jonker, S. A., R. M. Muth, J. F. Organ, R. R. Zwick and W. F. Siemer. 2006.
Experiences with beaver damage and attitudes of Massachusetts residents toward beaver.
Wildlife Society Bulletin. 34:1009-1021.
As stakeholder attitudes, values, and management preferences become increasingly diverse, managing human-wildlife conflicts will become more difficult. This challenge is especially evident in Massachusetts, USA, where furbearer management has been constrained by passage of a ballot initiative that outlawed use of foothold and body-gripping traps except in specific instances involving threats to human health or safety. Without regulated trapping, beaver (Castor canadensis) populations and damage attributed to them have increased. To develop an

understanding of public attitudes regarding beaver-related management issues, we surveyed a random sample of Massachusetts residents in the spring of 2002 within 3 geographic regions where beaver are prevalent, as well as all individuals who submitted a beaver-related complaint to the Massachusetts Division of Fisheries and Wildlife in 1999 and 2000. We found that respondents held generally positive attitudes toward beaver. Respondents who experienced beaver-related problems tended to have less favorable or negative attitudes toward beaver than people who did not experience beaver damage. Attitudes toward beaver became increasingly negative as the severity of damage experienced by people increased. We believe continued public support for wildlife conservation will require implementation of strategies that are responsive to changing attitudes of an urban population and within social-acceptance and biological carrying capacities.

Kebbe, C. E. 1949.
Oregon's beaver program.
Proceedings of the twenty-ninth annual conference of Western Association of State Game and Fish Commissioners, Seattle, Washington, June 14, 15, 16, 1949. 201-204.

Keigley, R. B. 2000.
Elk, beaver, and the persistence of willows in national parks: Comment on Singer et al. (1998).
Wildlife Society Bulletin. 28:448-450.

Lawrence, W. H. 1954.
Michigan beaver populations as influenced by fire and logging.
University of Michigan.

Fire, windthrow, and lumbering produce conditions favorable to beaver. Peak numbers of beaver follow widespread disturbances that set back forest succession. Beavers are primarily creatures of the aspen stage. Present beaver populations can persist only as long as aspen remains available within about 5 chains from water's edge. Management should not aim to halt succession at a desired stage, but to integrate beaver management into a forest management program similar in pattern to environmental change that occurs naturally in the aspen-conifer cycle. Management should be on a streamwise basis, with some streams producing beavers while others are recovering from beaver occupancy.

Libby, W. L. 1954.
A basis for beaver management in Alaska.
University of Alaska.

Liechty, W. R. 1954.
Statewide wildlife management surveys and investigations. Review of past management and population and distribution of beaver in the state of Utah.

Lisle, S. 2003.
The use and potential of flow devices in beaver management.
Lutra. 46:211-216.

After being nearly exterminated during the fur trade European beavers (Castor fiber) and American beavers (Castor canadensis) have been recovering and gradually re-flooding their long-vacant habitats in recent decades. This development has led to a growing conflict with humans. Flow devices are discussed as an alternative to beaver removal in controlling beaver-human conflicts. Flow devices control damming behaviour and therefore water levels. If well designed and well built they are a long lasting, low-maintenance method of preventing unwanted flooding. Furthermore, by negating the need to remove beavers from an area, flow devices allow for the possibility of other, non-threatening wetlands developing nearby. Consequently, flow devices represent an opportunity to preserve and restore wetlands.

Litvaitis, J. A. 2003.
Are pre-Columbian conditions relevant baselines for managed forests in the northeastern United States?
Forest Ecology and Management. 185:113-126.
Populations of a number of taxa associated with shrublands, early-successional forests, and other disturbance-generated habitats (collectively referred to as thickets) are declining in the northeastern United States. To assure that species dependent on thicket habitats persist, intervention is warranted. However, conservationists concerned with the status of thicket-dependent species are confronted with two important questions. How much habitat is needed? And how should these habitats be distributed? Natural disturbance regimes have been recommended as a baseline that managers should consider while providing thicket habitats. Within the Northeast, historic disturbance regimes varied substantially among forest types. Coastal regions were characterized by extensive barrens where regular and often times large-scale disturbances that resulted in >15% of the area being covered by regenerating forest stands. Among inland forests, natural disturbances were usually small and resulted in seedling-sapling stands and beaver (Castor canadensis) impoundments covering <6% of the area. Under these conditions, thicket-affiliated species were probably distributed in small, disjunct populations that shifted in space and time. Current efforts to maintain thicket habitats must deal with a range of current land-uses and a legacy of historic uses. Additionally, the effectiveness of management protocols that mimic natural disturbances is limited among many forests. Increasing ownership parcelization, a relatively young forest, and landscape fragmentation substantially reduce the practicality and suitability of small-scale disturbances for generating thicket habitats. Large, clustered patches may be more practical and beneficial, especially in urbanized landscapes. In rural areas, silvicultural manipulations should be applied on a "sliding scale" relative to forest age. Timber harvests that emulate the range of variability of natural disturbances may become appropriate in these areas as forest stands mature. Addressing the needs of thicket-dependent species in the northeastern United States will require creativity, a willingness to explore a variety of solutions, and public support.

Loker, C. A., D. J. Decker and S. J. Schwager. 1999.
Social acceptability of wildlife management actions in suburban areas: 3 cases from New York.
Wildlife Society Bulletin. 27:152-159 | 152.
Despite notable successes, wildlife damage management in suburban situations is widely perceived as difficult because of the vocal resistance of some suburban residents to many mitigation measures. We examined suburban residents' experiences with, concerns about, and acceptance of management actions for white-tailed deer (Odocoileus virginianus), beaver (Castor

canadensis), or Canada geese (Branta canadensis) in three areas of New York state. We considered four types of interventions which represented degrees of invasiveness to the animals of concern: human behavior modification, nonlethal-noninvasive, nonlethal-invasive, and lethal. Results demonstrated that residents' concerns about wildlife were elevated by increasingly severe problem experiences. In addition, residents' acceptance of invasive and lethal methods to resolve wildlife problems in suburban areas was higher than many wildlife managers might expect. Contrary to our predictions, acceptance of invasive and lethal methods was more strongly related to concerns about nuisance and economic damage issues than to concerns about health and safety issues. Our results provide useful information to wildlife professionals for management planning and communication regarding problem-causing wildlife in suburban areas.

Longcore, T., C. Rich, D. Muller-Schwarze and D. Mueller-Schwarze. 2007.
Management by Assertion: Beavers and Songbirds at Lake Skinner (Riverside County, California).
Environmental Management. 39:460-471 | 460-71.
Management of ecological reserve lands should rely on the best available science to achieve the goal of biodiversity conservation. "Adaptive Resource Management" is the current template to ensure that management decisions are reasoned and that decisions increase understanding of the system being managed. In systems with little human disturbance, certain management decisions are clear; steps to protect native species usually include the removal of invasive species. In highly modified systems, however, appropriate management steps to conserve biodiversity are not as readily evident. Managers must, more than ever, rely upon the development and testing of hypotheses to make rational management decisions. We present a case study of modern reserve management wherein beavers (Castor canadensis) were suspected of destroying habitat for endangered songbirds (least Bell's vireo, Vireo bellii pusillus, and southwestern willow flycatcher, Empidonax traillii extimus) and for promoting the invasion of an exotic plant (tamarisk, Tamarix spp.) at an artificial reservoir in southern California. This case study documents the consequences of failing to follow the process of Adaptive Resource Management. Managers made decisions that were unsupported by the scientific literature, and actions taken were likely counterproductive. The opportunity to increase knowledge of the ecosystem was lost. Uninformed management decisions, essentially "management by assertion," undermine the long-term prospects for biodiversity conservation. (Author)

Longley, W. H. and J. B. Moyle. 1963.
The beaver in Minnesota.

This bulletin is replete with information on history, economics, natural history and management of the beaver. Much of the information is based on data collected in Minn., but full use is also made of the literature. There are 77 titles listed in the bibliography. The appendix contains 2 articles from other publications: A guide to beaver trapping and pelting by Keith G. Hay and William H. Rutherford, and Grading of beaver pelts and manufacture of fur coats by Wendell G. Swank.

MacCracken, J. G. 2000.
Wildlife response to salmon habitat enhancements on the Bear River, southwest Washington.
Northwestern Naturalist. 81:82.

In 1997, large wood was added to 13 sites in the Bear River of southwest Washington and four kilometes of riparian red alder (Alnus rubra) forest were thinned and planted to conifer. Small mammal and amphibian abundance was similar (P=0.45) between thinned and control red alder stands from 1997-99. Beaver (Castor canadensis) activity increased and dam construction was often associated with an introduced large wood structure. edited by pcp.

McKinstry, M. C. and S. H. Anderson. 2002.
Survival, fates, and success of transplanted beavers, Castor canadensis, in Wyoming.
Canadian Field-Naturalist. 116:60-68 | 60.
Beaver (Castor canadensis) through their dam building activities, store water, trap sediment, subirrigate vegetation, and subsequently improve habitat for fish, wildlife, and livestock. Many landowners realize the benefits that Beaver can bring to a riparian area and are interested in using them to improve this habitat. From 1994 to 1999 we trapped and relocated 234 Beaver to 14 areas throughout Wyoming to improve riparian habitat and create natural wetlands. We attached radio transmitters to 114 Beaver and subsequently determined movements and mortality of released Beaver, and the overall success of our releases. Mortality and emigration (including transmitter failure) accounted for the loss of 30% and 51%, respectively, of telemetered Beaver within 6 months of release. Kaplan-Meier survival estimates were 0.49 (SE=0.068) for 180 days and 0.433 (SE=0.084) for 360 days, and did not differ significantly between age classes. On average, 17 Beaver were transplanted to each release site, and at 11 locations, in an attempt to augment single Beaver that had become established and increase transplant success, we transplanted Beaver in two or more years. Success of an individual Beaver's relocation was unrelated to any of the variables we tested, although 2-3.5 year-old Beaver had higher average success (measured in days of occupancy at the release site) than older animals. Animals <2 years old had 100% mortality and emigration losses within 6 months of release. High predation and mortality rates of our released Beaver may be due to habitat (our streams were shallow with no ponds and provided little protection) and extensive predator communities. We established Beaver at 13/14 of our release sites and they eventually reproduced. Our results show that Beaver can be relocated successfully but losses from mortality and emigration need to be considered and planned for.

Meyers, A. V. 1946.
Beaver management in Oregon.
1:1.
Early value of beaver pelts in the fur trade; laws and regulations for protection of the animal; tabulation of number of pelts taken 1923-24 to 1928-29; trapping and transplanting to restore the species; control of beaver damage; results of cooperative land-owner-game commission management.

Nelson, U. C. 1954.
Wildlife investigations of Alaska: Beaver management studies --Aerial survey of beaver.
9:12-14. Alaska Department of Fish and Game.

Parsons, G. R. and M. K. Brown. 1978.
An assessment of aerial photograph interpretation for recognizing potential beaver colony sites.
New York Fish and Game Journal. 25:175-177.

Parsons, G. R. and M. K. Brown. 1981.
Season length as a method of achieving population objectives for beaver (Castor canadensis).
Proceedings of the Worldwide Furbearer Conference. 1392-1403.

Patric, E. F. 1952.
A beaver management program for the Huntington Forest.
Syracuse University.

Payne, N. F. 1981.
Accuracy of aerial censusing for beaver colonies.
Journal of Wildlife Management. 45:1014-1016.

Payne, N. F. 1984.
Population dynamics of beaver in North America.
Acta Zoologica Fennica. 263-266.

Peterson, R. P. and N. F. Payne. 1986.
Productivity, size, age, and sex structure of nuisance beaver colonies in Wisconsin.
Journal of Wildlife Management. 50:265-268 | 265.

Rasmussen, D. I. and N. West. 1943.
Experimental beaver transplanting in Utah.
311-318.
Report upon investigations designed to improve methods. summary: "(1) An experimental beaver and transplanting program was carried out in Utah during July, August and September of 1940. A total of 150 beavers were trapped; (2) the Scheffer-Couch beaver live trap was used very successfully throughout the season. The Hancock beaver live trap also proved to be a successful trap, especially adapted for the trapping of steep banks and deep water; (3) sexes of all animals were determined without internal examination; (4) all beaver were tagged in each ear with a small strap type tag to insure better chances of returns; (5) a sheet metal pen with a bottom of heavy screen was used to hold the beaver until time for transplanting. This pen could be dismantled and hauled flat in a pick-up; (6) beavers were transported in specially built crates which had watertight bottoms permitting holding of water when desirable." Bibliography of 8 titles.

Rawley, E. V. 1954.
Statewide wildlife management surveys and investigations: Utah beaver transplanting manual.

Reid, K. A. 1951.
Planning for wildlife on a managed forest.
Journal of Forestry. 49:436-439.
Timber, fish, and beaver management on the 96,000-acre Whitney Park in the Adirondacks of northern New York.

Retzer, J. L., H. M. Swope, J. D. Remington and W. H. Rutherford. 1956.

Suitability of physical factors for beaver management in the Rocky Mountains of Colorado.

269 miles of 61 streams in w. Colo. were studied. Role of beaver in creating "beaver meadows" is questioned; geology of site seems more influential. Stream grades of more than 15% are not used by beaver; grades of 1-6% are best. Narrow valleys are unfavorable but not limiting unless no wider than channel. The wider the valley the better. Sites with easily eroded rocks such as shale or shale-sandstone are unsuitable because of likelihood of highly damaging washouts. Hard rocks and glacial till are favorable. These factors are combined to form a classification of sites as excellent, good, questionable, or unsuitable for beaver. Planting and control of beaver should be governed by site classification. Numerous photographs, 11 graphs, and 5 tables help give good understanding of points discussed.

Scheffer, V. B. 1941.
Management studies of transplanted beavers in the Pacific Northwest.
320-325.
"There are three important phases in management of the beaver in the Pacific Northwest: (1) Protecting the animal as a producer of fur, (2) removing it from highly cultivated lands, and (3) putting it to work as an agent in soil and water conservation in mountain meadows. In the present stage of land use in the Pacific Northwest, and for some years to come, to manage the beaver as a producer of fur is less important than to use it as a soil and water engineer." In the author's opinion, the open season for public trapping of beavers has had unfortunate results. He believes that trapping should be done only by trained game officers. The results of transplanting operations are summarized in a table. Three-fourths of the liberated colonies disappeared from the planting site in a few days or weeks. Eight principal reasons for this are suggested. The food relations of beaver colonies are discussed under four heads and the principal food trees of the animals are listed. Rates of tree cutting and lodge and dam construction are cited. The average amount of water stored by a colony at the end of the third year was about 15,000 cubic feet. Author's conclusions: "(1) The number of beavers dead-trapped where they are doing damage should be increased; (2) the causes that contribute to the failure of plantings are sufficiently well known that, by careful attention to the selection of sites, the game manager can establish 60 per cent of the colonies released; (3) considering the wide variety of habitats under which beavers are known to thrive, it is not practicable to determine before-hand, by the use of numerical standards only, the carrying capacity of a prospective planting site."

Schulte, B. A., D. Muller-Schwarze and L. Sun. 1995.
Using anal gland secretion to determine sex in beaver.
Journal of Wildlife Management. 59:614-618 | 614.
Develops a technique using color and viscosity of anal gland secretion (AGS) to identify gender of beaver. Facilitation of beaver management by determining sex ratio of a population; Difference and viscosity of AGS between males and females of all ages; Accuracy of palpitation method to determine gender.

Shaw, S. P. 1948.
The beaver in Massachusetts, a research and management study.
Mass. Dep. Conserv. Div. Wildl. Res. Manage. Res. Bull.

Beaver appeared in western Massachusetts in 1928 after an absence of about 150 years. Since then they have become both a nuisance and a potentially valuable resource. This study was made in 1947 and 1948. It included (1) locating all the colonies in the State, (2) determining the potential range, (3) establishing methods for estimating the annual population, (4) determining methods of harvest, (5) determining the practicability of live trapping and transplanting, and (6) recommending laws relative to management.

Siemer, W. F., T. L. Brown, S. A. Jonker and R. M. Nuth. 2003.
Attitudes Toward Beaver and Beaver Management: Results from Baseline Studies in New York and Massachusetts.

Singer, F. J., L. C. Zeigenfuss and D. T. Barnett. 2000.
Elk, beaver, and the persistence of willows in national parks: Response to Keigley (2000).
Wildlife Society Bulletin. 28:451-453.

Slough, B. G. and R. M. F. S. Sadleir. 1977.
A land capability classification system for beaver (Castor canadensis Kuhl).
Canadian Journal of Zoology. 55:1324-1335.

Snyder, C. D., J. A. Young and B. M. Stout III. 2006.
Aquatic habitats of Canaan Valley, West Virginia: Diversity and environmental threats.
Northeastern Naturalist. 13:333-352.
We conducted surveys of aquatic habitats during the spring and summer of 1995 in Canaan Valley, WV, to describe the diversity of aquatic habitats in the valley and identify issues that may threaten the viability of aquatic species. We assessed physical habitat and water chemistry of 126 ponds and 82 stream sites, and related habitat characteristics to landscape variables such as geology and terrain. Based on our analyses, we found two issues likely to affect the viability of aquatic populations in the valley. The first issue was acid rain and the extent to which it potentially limits the distribution of aquatic and semi-aquatic species, particularly in headwater portions of the watershed. We estimate that nearly 46%, or 56 kilometers of stream, had pH levels that would not support survival and reproduction of Salvelinuw fontinalis (brook trout), one of the most acid-tolerant fishes in the eastern US. The second issue was the influence of Castor canadensis (beaver) activity. In the Canaan Valley State Park portion of the valley, beaver have transformed 4.7 kilometers of stream (approximately 17% of the total) to pond habitat through their dam building. This has resulted in an increase in pond habitat, a decrease in stream habitat, and a fragmented stream network (i.e., beaver ponds dispersed among stream reaches). In addition, beaver have eliminated an undetermined amount of forested riparian area through their foraging activities. Depending on the perspective, beaver-mediated changes can be viewed as positive or negative. Increases in pond habitat may increase habitat heterogeneity with consequent increases in biological diversity. In contrast, flooding associated with beaver activity may eliminate lowland wetlands and associated species, create barriers to fish dispersal, and possibly contribute to low dissolved oxygen levels in the Blackwater River. We recommend that future management strategies for the wildlife refuge be viewed in the context of these two issues, and that the responses of multiple assemblages be incorporated in the design of refuge management plans.

Spriggs, J. W. 1943.
Rehabilitating the beaver.
Wyoming Wildlife. 8:1-5.
Trapping of beavers in over-populated areas and transplanting them in other localities has been undertaken by the Wyoming Game and Fish Department. Trapping methods are described as are also several types of sets, namely, channel, forage, dam, house, scent, heap, and artificial scent. Care and skill are required in properly setting traps for best results as the animals become very cautious and difficult to capture after one experience with a trap. Instructions are given on the handling and transportation of beavers. "Selected future habitat should be surveyed carefully in advance of liberation, to determine the most favorable sites for planting. Main requirements for a satisfactory beaver habitat are (1) a year-round supply of running water of sufficient volume, (2) food of sufficient supply and variety, (3) satisfactory gradient and elevation, (4) protection from poachers." "Beaver should not be planted in a new area in numbers less than two pairs; lots of three or four pairs are preferred."

Stevens, C. E., C. A. Paszkowski and G. J. Scrimgeour. 2006.
Older is better: beaver ponds on boreal streams as breeding habitat for the wood frog.
Journal of Wildlife Management. 70:1360-1371.
Succession of stream ponds mediated by beaver (Castor canadensis) damming and foraging in riparian zones may contribute to changes in amphibian populations. Our study examined the use of beaver ponds by the wood frog (Rana sylvatica) in a network of boreal streams in west-central Alberta, Canada. We quantified relations between breeding populations of wood frogs estimated from call surveys and pond age and riparian canopy cover, and we compared an index of juvenile recruitment to metamorphosis estimated with pitfall trap captures between new (< 10 yr) and old (> 25 yr) beaver ponds. We also conducted an in-pond enclosure experiment to determine if differences in physicochemical conditions of new versus old ponds influenced larval performance. Regression and Akaike's Information Criterion model averaging indicated that both density and calling intensity of male wood frogs at beaver ponds had a negative relationship with percent riparian canopy cover and had a positive relationship with pond age. The best a priori statistical models, however, included riparian canopy cover rather than pond age as a significant covariate. Old ponds had reduced riparian canopy and greater abundance of submergent vegetation, thermal degree-days, and dissolved oxygen concentrations compared to newly formed ponds. While survival of larval wood frogs in enclosures did not differ between pond age classes, growth and development rates in old ponds were greater than in new ponds. In addition to warmer water in old ponds, results from a laboratory experiment suggest that higher concentrations of dissolved oxygen characteristic of old ponds can enhance larval growth rates. Older beaver ponds may support more breeding wood frogs due to adult selection for open-canopy ponds and the associated larval environments favourable for high rates of juvenile recruitment. Forest management that protects beaver and their food supplies may also promote healthy populations of boreal amphibians.

Swafford, S. R. 2003.
Population Survey Methods, Immobilization Approaches, and Morphological Characteristics for Beaver in Lowndes County, Mississippi (Castor Canadensis).
41:716-112. Mississippi State University.

Wildlife damage management requires that resource managers implement control methods that are effective at reducing wildlife damage while minimizing public sentiment and impacts to non-target species. Attempts were made to estimate beaver populations through spotlight surveys from banks and water of wetlands to better prepare damage reduction projects. Overall, spotlight surveys proved to be ineffective at accurately estimating beaver populations. Mark-recapture and mark-resighting of beaver for population estimation also proved to be ineffective. Habitat characteristics influenced spotlight counts on differing wetlands. Mean viewing distance was longest for bank and boat spotlight surveys on wetlands which contained moderate (30-50%) woody tree coverage. Mean distance to individual beaver spotlighted from the bank was longest on sites with greater than 50% open water. However, mean distance to individual beaver spotlighted from a boat was longest on sites with moderate (30-50%) woody tree coverage. Localized beaver populations on six study sites were effectively indexed by area and perimeter distance. However, these beaver populations could not be effectively indexed by lodges, beaver dams, bank dens, scent mounds, or food caches. Tiletamine hydrochloride and zolazepam hydrochloride (Telazol(R)) proved to be effective for immobilizing beaver in the field. Induction and immobilization times were considered short; however, recovery times were long for field immobilization. Weight, overall length, tail length, skull width, and skull breadth can be used to place beaver in adult/sub-adult age classes. However, tail width and area of tail dimensions showed variations between genders which did not allow for placing beaver in age classes. Beaver can be accurately sexed by external palpation; however, morphological measurements did not allow for gender determination.

Swank, W. G. 1949.
Beaver ecology and management in West Virginia.

Beaver were reintroduced in West Virginia between 1933 and 1940, and now are about as common in the State as desirable. They are principally in the Allegheny Plateau. Serviceberry is their favorite food. They benefit muskrat, raccoon, mink, waterfowl, and woodcock, but destroy winter cover for deer and grouse. They are a local problem with respect to trout. They should be confined to about their present range and population by the annual removal of about 700 animals. A cooperative management plan is in operation on the Monongahela National Forest.

Swimley, T. J., R. P. Brooks and T. L. Serfass. 1999.
Otter and beaver interactions in the Delaware Water Gap National Recreation Area.
Pennsylvania Academy of Science. Journal. 72:97-101.
Beaver populations have expanded throughout the Northeast and Mid-Atlantic states in recent years. This population expansion has resulted in an increase in complaints related to habitat modifications by beavers. Fur trapping has been the preferred management tool for beaver; however, there can be substantial incidental captures and deaths of non-target species, especially river otters. The authors conducted surveys of 65 riparian habitat reaches along 64 km of streams and ponds in the Delaware Water Gap National Recreation Area (DWGNRA) from April-July, 1998 to assess the current locations of beaver colonies, and determine how otters and beavers interacted in various riparian habitats. During ground surveys, they located 27 active and 45 inactive beaver lodges and 61 otter latrines. Thirty-four (52%) survey reaches contained active or inactive beaver habitats and 71% of survey reaches with active or inactive beaver sign showed evidence of otter use. Fifty-eight (95%) otter latrines were associated with survey

reaches currently or previously occupied by beavers. There was a significant positive relationship between presence of beaver activity (active or abandoned) within a survey reach, and otter use (X²=24.8, P<0.001). Many otter latrines (34%) were within 50 m of active or inactive beaver lodges. Eighty-one percent of active beaver lodges and 85% of otter latrines were located in lake- or pond-dominated survey reaches and low-gradient stream sections. Beaver activity was uncommon in high-gradient habitats, and otter latrines were uncommon in non-beaver habitats. A management program that targets specific beaver colonies and includes the use of snares, padded leg-hold traps, firearms, and professionally trained personnel will minimize impacts on otters. Additional use of water level control devices is preferred over lethal means, whenever possible.

Townsend, J. E. and F. E. Newby. 1955.
Montana beaver management.

In 1953 the Mont. Game Dept. got authority to prescribe beaver regulations. The system and how it is handled are described here. The system seems noteworthy for complexity, flexibility, and adequacy. The area unit is the warden district; the warden administers local aspects of the system, assigns trapping areas, advises on population levels, etc. Levels are also determined by aerial survey, harvest data, and reports on damage alleviation. A quota is set for each area; it is prorated among trappers who have applied to trap in that area. Where sustained yield is desired, seasons are set for spring, when pelts are best and when {male}{male} will have mated. Population reduction is achieved by fall trapping, omission of royalty fees, and declaration of "no limit" areas. Pelts must be tagged before transport and again before sale. Tag numbers allow technicians to determine locality of origin of a pelt. Age groups and hence relative reproductive success are determined from size groups of pelts. Indications are that population was at saturation point in most areas, and that young were most numerous where populations were not densest. Tables show monthly variation in pelt prices, monthly variation in sex ratio of trapped beaver, and relationship of age ratio to population density.

Twichell, R. 1952.
National status of beaver and beaver management.
476-482.
"This paper describes the history of beaver management in Missouri and summarizes the various management methods of other states and provinces." The problem in many areas today is to get a sufficiently heavy harvest to prevent waste, damage, and habitat exhaustion. Some figures are given on numbers of beavers now trapped annually. The average for 26 U. S. states was 4,535 in 1951. In Canada, more than 188,000 were pelted. Recent increases have been great.

Whitaker, J. 1995.
Private beaver management in Oklahoma.

Efforts to control beaver populations result in increasing the beaver's productivity. As a result the goal of the Oklahoma Department of Wildlife Conservation, has been to relieve damage caused by beavers to property without participating in population reduction. At present, nuisance beaver control permits allow beaver to be taken on private or public lands with body-gripping traps or night shooting. lgh.

Williams, R. M. 1965.
Beaver habitat and management.
Idaho Wildlife Review. 17:3-7.
Of the 44,000 miles of Idaho streams, 50% is unsuitable because slopes are too steep and 17% because of use by man. Beaver population density has been one colony per 1.3 to 1.7 miles during the past five years, based on surveys made annually of more than 400 miles of Idaho streams.

Wire, F. B. and A. B. Hatch. 1943.
Administration of beaver in the western United States.
Journal of Wildlife Management. 7:81-92.
The authors estimate that in 1940-41 there were about 324,000 beavers in 11 western states and that nearly 54,000 pelts of a value in excess of a million dollars were harvested. In most of these states there is no legal provision for taking beavers except to control damage, incentive for private beaver management is lacking, and no satisfactory means has been devised of stopping interstate traffic in contraband skins. Each of these shortcomings is discussed and recommendations are made for overcoming them. The good and harm done by the animals also are detailed. Editorially, it may be pointed out that employing beaver as a plural is English, rather than American, usage and that the term "hot" is slang for contraband, a word that does not appear in the paper.

Woodward, D. K. 1983.
Beaver Management in the Southeastern United States: a review and update.
Proceedings of the Eastern Wildlife Damage Control Conference. 1:163-165.

Yeager, L. E. and W. H. Rutherford. 1957.
Ecological basis for beaver management in the Rocky Mountain region.
Transactions of the 22nd North American Wildlife Conference.
Overpopulations of beavers in the region cause serious destruction to mountain stream habitats in some localities. But balance between beaver numbers and range conditions has favorable effects on trout, waterfowl, aquatic fur animals, and other wildlife. An adequate harvest, difficult during the present era of low fur prices, is now the primary management objective in most of the West. Studies have led to development of beaver management plans based on carrying capacity of ranges as determined by physical characteristics of streams, quantity and quality of food, productivity, competition from livestock and big game, and beaver numbers. A practical Beaver census technique has been developed for mountain range, primarily small streams. Harvest, attuned to sustained yield on areas suitable to beaver occupancy, is based on trends in beaver numbers and range condition, and may be set readily at levels giving increasing, static, or decreasing populations. Beavers in damage status are managed according to contingencies involved, usually by exhaustive trapping. Forms for recording field and management data, resulting in uniformity in procedure, are illustrated. Seasonal management jobs are given in sequence.--L. E. Yeager.

Zeckmeister, M. T. and N. F. Payne. 1998.

Effects of trapping on colony density, structure, and reproduction of a beaver population unexploited for 19 years.
Wisconsin Academy of Sciences, Arts and Letters. Transactions. 86:281-291.
The authors studied the influence of trapping on colony density, structure, and reproduction of a beaver population that had not been trapped in 19 years. After 19 years of being closed to trapping, the beaver colony density in the Sandhill Wildlife Area of Wisconsin was 1.30 colonies/km2 compared to an adjacent trapped area which had a density of 0.42 colonies/km2. A winter harvest of 3.9 beavers/colony in 1981 resulted in a 21% decline in active colonies in 1982. The harvest of 3.2 beavers/colony in 1982 resulted in a 53% decline in 1983. slj.

Zimmerman, F. R. 1943.
Water levels in relation to fur bearers and waterfowl in central Wisconsin.
Wisconsin Conservation Bulletin. 8:23-26.
Flowages created by Federal aid have provided environment for fur animals and for water, marsh, and shore birds, have reduced fire hazards, and raised water tables. Benefits to wildlife on 35 flowages are discussed, and recommendations are made as to management of beavers, muskrats, and waterfowl; as well as of water levels. Bibliography of 7 titles.

Monitoring and survey methods

Broschart, M. R., C. A. Johnston and R. J. Naiman. 1989.
Predicting beaver colony density in boreal landscapes.
Journal of Wildlife Management. 53:929-934.

Brown, M. K. and G. Parsons. 1979.
Reliability of fall aerial censuses in locating active beaver colonies in northern New York.
Transactions of the Northeast Section of the Wildlife Society. 36:192-194.

Brown, M. K. and G. R. Parsons. 1982.
Reliability of fall aerial censuses for locating active beaver colonies in northern New York.
New York Fish and Game Journal. 29:204-206.

Danell, K., T. Willebrand and L. Baskin. 1998.
Mammalian herbivores in the boreal forests: their numerical fluctuations and use by man.
Conservation Ecology. 2:1-20.
The authors present an account of the population fluctuations of mammalian herbivores occurring in the boreal forests of the Nearctic and Palaearctic and their interrelation with humans. The boreal forests support rich natural resources that have been used over centuries by mankind for survival. The mammalian species are the most important resource that have provided man with food and products of commercial importance like antlers and hides. Their impact on plant succession, and their role in increasing the wetland mosaic and altering the hydrology of important ecosystems is also significant. These mammalian herbivores exhibit fluctuating cycles that are evident on different trophic levels. There are three types of fluctuations. The first two groups contain species with regular fluctuations and the third group contains species with irregular fluctuations. Thus, a variation in population size that lacks stable resource-dependent equilibrium seems to be characteristic of population fluctuations of many

large ungulates. This study indicated that forest management that reduces the structural and spatial diversity at the stand, as well as at the landscape, level affects boreal forest habitats. Management of silvicultural that supports same age trees improves conditions for species favoring young forest stands, but it makes the situation worse for species that depend on old-growth forests. Another aim of management is the attempt at successful increase of population sizes of mammals. However, this population increase might go out of control leading to destabilization and destruction. Therefore it can be concluded that management of boreal forest ecosystems should be both substantial and long lasting.

Dickins, J. H., D. W. Clark, S. C. White and G. A. Heidt. 1999.
Survey of medium and large mammals in an urban park (Murray Park), Little Rock, Pulaski County, Arkansas.
J. Arkansas Acad. Sci. 53:41-44.
Because of increased environmental awareness by city planning commissions, there are more urban parks and greenbelt areas. These areas often result in increased human and wildlife contacts, thus resulting in the need for management plans regarding urban wildlife. From September 1998 to March 1999, we conducted mammal surveys of the urban greenspace Murray Park, Little Rock, Pulaski County, Arkansas. Surveys were conducted using five methods: direct observations; spot lighting; live trapping; animal sign; and scent posts. Species recorded included, opossum (Didelphis virginiana), nine-banded armadillo (Dasypus novemcinctus), fox squirrel (Sciurus niger), gray squirrel (Sciurus carolinensis), beaver (Castor canadensis), woodchuck (Marmota monax), muskrat (Ondatra zibethicus), eastern cottontail rabbit (Sylvilagus floridanus), swamp rabbit (Sylvilagus aquaticus), coyote (Canis latrans), red fox (Vulpes vulpes), raccoon (Procyon lotor), mink (Mustela vison), river otter (Lontra canadensis), bobcat (Lynx rufus), skunk sp., white-tailed deer (Odocoileus virginianus) and domestic dog (Canis familiaris) and cat (Felis sylvestris). These species represent 19 of the 23 mammals expected in surrounding natural areas. Management plans for urban wildlife need to include all mammals that potentially occur in the area.

Easter-Pilcher, A. 1990.
Cache size as an index to beaver colony size in northwestern Montana.
Wildlife Society Bulletin. 18:110-113.
Direct and indirect indices of beaver colony size that could be useful for monitoring population fluctuations were investigated.

Gray, M. H. and D. H. Arner. 1977.
The Effects of Channelization on Furbearers and Furbearer Habitat.
31:259-265.
Biological data were collected over a 3 year period (1974-1977) from an old channelized segment (55 years), an unchannelized segment and a newly channelized segment (4 years) of the Luxapalila River in Mississippi and Alabama. This study revealed that furbearer habitat in the channelized segments has not recovered to the level exhibited in the unchannelized segment. Indices of furbearer abundance were obtained by night lighting and sign counting. Beaver (Castor canadensis), mink (Mustela vison), muskrat (Ondatra zibethicus), and raccoon (Procyon lotor) were more numerous in the unchannelized segment than in either the old or newly channelized segments.

Hammerson, G. A. 1994.
Beaver (*Castor canadensis*): Ecosystem alterations, management, and monitoring.
Natural Areas Journal. 14:44-57.

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

Thirteen beaver colonies were investigated over 2 summer and fall periods. Live and dead-trapping, pond draining, ground observations, and dislodging with smoke were tested in obtaining basic colony-composition data. Only dead-trapping proved quick and reliable as an intensive census method. Beaver dams, scent mounds, size of main lodge, and number of lodges proved invalid as population indices. The lodge was not indicative of the colony; one colony may keep at least 3 different lodges in good repair. Colonies subsisting on aspen contained a significantly larger number of individuals (7.8) than colonies subsisting on willow (5.1). Over-wintering colonies av. 6.3 ± 1.3 beavers. Aerial coverage of drainages, using the food cache as an index, was both accurate and practical. There was always 1 food cache per colony and the cache, always surrounded by water, could be recognized easily. A reliable census of beaver populations in mountainous terrain may be obtained by counting the number of food caches in an area in late Sept. or Oct. and multiplying by av. number of beavers per winter colony.--Author.

Hensley, A. L. and B. C. Fox. 1948.
Experiments on the management of Colorado River beaver.
California Fish and Game. 115 | 34:15-131 | 115-131. California Department of Fish and Game.

The authors report on the study which California and Arizona made during the period 1943-1947. Surveys to determine density of population and to evaluate the effects of cropping were made each year along the portion of the river between the two states. It was found that "Harvesting beaver on a per pelt basis proved more satisfactory than on a basis of salaried trappers. Equipment purchased by the states made it possible to maintain a higher efficiency in the trapping activity by reducing the loss in trapped animals and damage to pelts. Systematic trapping requires close supervision or the animals will not be cropped to the best advantage or in the predetermined numbers." "The fact that this program has been more than self sustaining, yielding a substantial profit credited to the participating states, justifies continuance of the management study."--M. Alberts.

Hodgdon, K. W. and J. H. Hunt. 1953.
Beaver management in Maine.

Detailed paper based on work of several men since 1946. It should be seen by anyone concerned with beaver management. Much of the biological information cannot be mentioned in a brief review. Among major topics are history in state, weights and measurements, life history, ecological relations to other animals, economics, and management recommendations. Some of the graphs show (usually by age groups): incisor width, skinned weights, tail area, hind foot length, furred length, total length, breeding dates calculated from embryo weights, growth of young, and size groups of pelts. Predation on beaver was insignificant. Parasitism (reported quantitatively) was common but seemed to be of no population importance. Effect of beaver on other game was beneficial. Effect on trout was often beneficial, sometimes harmful. Effect on valuable timber was slight, and most big timber owners favor present beaver populations, partly because they aid fire control. Beaver populations and carrying capacity were determined for each township of state; management will be based partly on these figures. Trapping season should be in March, after mating season. Trapping should be regulated by township or stream, with closure when necessary, and with length of season set for state by game commission. Beaver farming was found to be unprofitable.

Kafcas, E. N. 1987.
Census and exploitation of a discrete beaver population in Michigan.
1987:89. Central Michigan University.

Purpose was to develop a census technique, while evaluating beaver exploitation rates under 1979 and 1980 trapping regulations. The census technique related year-to-year changes in colony population size with numbers of colonies present, using the food cache method. Data concerning reproduction, population dynamics,. age, weight and movements, and habitat condition were collected to assess effects of trapping regulations.

Kohn, B. E. and J. E. Ashbrenner. 1995.
Beaver Population Status.
Wisconsin Department of Natural Resources. 1995:26.
Procedures for monitoring Wisconsin's beaver population were developed that could be used to evaluate the effectiveness of population management programs. A helicopter survey was developed capable of estimating regional beaver populations at a reasonable cost.

Lawrence, W. H. 1952.
Evidence of the age of beaver ponds.
Journal of Wildlife Management. 16:69-79.
Describes use of tree and shrub growth rings and various historical evidence such as previous surveys and personal interviews with residents.

Osmundson, C. L. and S. W. Buskirk. 1993.
Size of food caches as a predictor of beaver colony size.
Wildlife Society Bulletin. 21:64-69 | 64.
The relationship between cache size and colony size was studied, the precision and accuracy of aerial estimates of cache size were assessed, and factors other than colony size that could explain variation in the size of beaver cache were investigated. Study areas were established in the Fox Park area of the Medicine Bow National Forest, and near South Pass City.

Parsons, G. R. and M. K. Brown. 1978.
An assessment of aerial photograph interpretation for recognizing potential beaver colony sites.
New York Fish and Game Journal. 25:175-177.

Payne, N. F. 1981.
Accuracy of aerial censusing for beaver colonies.
Journal of Wildlife Management. 45:1014-1016.

Robb, D. L. 1942.
A beaver census in Algonquin Provincial Park, 1939-1940.
Canadian Field-Naturalist. 56:86-90.
Full description of the methods of the census which was on a sample plot basis. The probable number of fresh beaver houses in the Park is 2,204. The animals were concentrated in the center of the park and were notably scarcer adjacent to boundaries (due to poaching?). The habitat, dams, and lodges are described and careful notes on foods presented. The following were much sought: grasses, leaves of maple and raspberry, roots of yellow water-lily, and barks of white and yellow birches and of aspen. In burned-over areas, where conditions favored regeneration of conifers, the beavers tend to eat out the food supply; in hardwood forests their tenure appeared to be longer.

Robel, R. J. and L. B. Fox. 1993.
Comparison of aerial and ground survey techniques to determine beaver colony densities in Kansas.
Southwestern Naturalist. 38:357-361.

Robel, R. J., L. B. Fox and K. E. Kemp. 1993.
Relationship between habitat suitability index values and ground counts of beaver colonies in Kansas.
Wildlife Society Bulletin. 21:415-421 | 415.

Swafford, S. R. 2003.
Population Survey Methods, Immobilization Approaches, and Morphological Characteristics for Beaver in Lowndes County, Mississippi (Castor Canadensis).
41:716-112. Mississippi State University.

Wildlife damage management requires that resource managers implement control methods that are effective at reducing wildlife damage while minimizing public sentiment and impacts to non-target species. Attempts were made to estimate beaver populations through spotlight surveys from banks and water of wetlands to better prepare damage reduction projects. Overall, spotlight surveys proved to be ineffective at accurately estimating beaver populations. Mark-recapture and mark-resighting of beaver for population estimation also proved to be ineffective. Habitat characteristics influenced spotlight counts on differing wetlands. Mean viewing distance was longest for bank and boat spotlight surveys on wetlands which contained moderate (30-50%) woody tree coverage. Mean distance to individual beaver spotlighted from the bank was longest on sites with greater than 50% open water. However, mean distance to individual beaver spotlighted from a boat was longest on sites with moderate (30-50%) woody tree coverage. Localized beaver populations on six study sites were effectively indexed by area and perimeter distance. However, these beaver populations could not be effectively indexed by lodges, beaver dams, bank dens, scent mounds, or food caches. Tiletamine hydrochloride and zolazepam

hydrochloride (Telazol(R)) proved to be effective for immobilizing beaver in the field. Induction and immobilization times were considered short; however, recovery times were long for field immobilization. Weight, overall length, tail length, skull width, and skull breadth can be used to place beaver in adult/sub-adult age classes. However, tail width and area of tail dimensions showed variations between genders which did not allow for placing beaver in age classes. Beaver can be accurately sexed by external palpation; however, morphological measurements did not allow for gender determination.

Swank, W. G. and F. A. Glover. 1948.
Beaver censusing by airplane.
Journal of Wildlife Management. 214:West Virginia Department of Natural Resources.

On a flight in April 1947 in West Virginia, 103 miles of stream with over 50 beaver colonies were covered in 45 minutes. The total cost was 21.50. It would have been practically impossible to census the area on foot. There are 2 sources of error in this kind of census: difficulty in determining the number of colonies where a stream has many dams close together, and failure to determine the number of bank beaver. A fall census would be more satisfactory than a spring census. For safety in rough country a plane should have plenty of power.

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

Swimley, T. J., R. P. Brooks and T. L. Serfass. 1999.
Otter and beaver interactions in the Delaware Water Gap National Recreation Area.
Pennsylvania Academy of Science. Journal. 72:97-101.
Beaver populations have expanded throughout the Northeast and Mid-Atlantic states in recent years. This population expansion has resulted in an increase in complaints related to habitat modifications by beavers. Fur trapping has been the preferred management tool for beaver; however, there can be substantial incidental captures and deaths of non-target species, especially river otters. The authors conducted surveys of 65 riparian habitat reaches along 64 km of streams and ponds in the Delaware Water Gap National Recreation Area (DWGNRA) from April-July, 1998 to assess the current locations of beaver colonies, and determine how otters and beavers interacted in various riparian habitats. During ground surveys, they located 27 active and 45 inactive beaver lodges and 61 otter latrines. Thirty-four (52%) survey reaches contained active or inactive beaver habitats and 71% of survey reaches with active or inactive beaver sign showed evidence of otter use. Fifty-eight (95%) otter latrines were associated with survey reaches currently or previously occupied by beavers. There was a significant positive relationship between presence of beaver activity (active or abandoned) within a survey reach, and otter use (X²=24.8, P<0.001). Many otter latrines (34%) were within 50 m of active or inactive beaver lodges. Eighty-one percent of active beaver lodges and 85% of otter latrines were located in lake- or pond-dominated survey reaches and low-gradient stream sections. Beaver activity was uncommon in high-gradient habitats, and otter latrines were uncommon in non-beaver habitats. A management program that targets specific beaver colonies and includes the use of snares, padded leg-hold traps, firearms, and professionally trained personnel will

minimize impacts on otters. Additional use of water level control devices is preferred over lethal means, whenever possible.

Wilson, B. S. and G. M. McEwen. 1998.
Will continued monitoring of beaver damaged resources minimize future damage?
Proceedings of the Eighteenth Vertebrate Pest Conference. 213-220.
The authors examined the possibility that continued monitoring and removal of beavers from previously controlled beaver damage sites resulted in less additional damage than not monitoring such sites. Beavers were removed from 34 sites in nine southeastern Texas counties from August 1996 through March 1997. Sixteen sites were subsequently monitored monthly and, if beavers had reinvaded, they were removed and the additional damage value was recorded. The remaining eighteen sites were not monitored, but were visited at the end of the study period. The larger average damage values for reinvaded unmonitored sites compared to reinvaded monitored sites would be important to landowners when deciding if property should be monitored. klf.

Woodward, D. K., J. D. Hair and B. P. Gaffney. 1976.
Status of Beaver in South Carolina as Determined by a Postal Survey of Landowners.
30:448-454.
A postal survey in 1975 of 4,500 landowners was conducted in South Carolina concerning the presence of Beavers on their properties. Objective was to determine the distribution, economic impact and landowner attitudes regarding beavers on their properties.

Zorichak, J. L. 1947.
Minnesota's conservation air-arm.
The Conservation Volunteer. 7:
Aerial censusing has been successful in Minnesota with big game, beaver, muskrat, waterfowl, and prairie chickens. Observations from low altitudes have been useful in mapping aquatic vegetation. The Stinson Voyager has proved the best plane for this work.

Population dynamics and demographics

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

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

Boyce, M. S. 1974.
Beaver population ecology in interior Alaska.
161:University of Alaska.

University of Alaska Thesis.Two populations of beaver were studied and correlated to trapping intensity. Descripton of the use of the pelvis in sex determination.

Boyce, M. S. 1981.
Beaver life-history responses to exploitation.
Journal of Applied Ecology. 18:749-753.
Human exploitation of beavers decreases the survivorship of adults, but by freeing high quality colony sites, results in enhanced survivorship for dispersing prereproductives. Females breeding earlier in life in an exploited population attain smaller size at maturity and consequently suffer higher mortality than individuals breeding Later at a larger body size. These trade-offs between fecundity, growth and survivorship are as predicted by recent theory on the evolution of life-histories. (Author)

Brooks, R. P. 1977.
Induced sterility of the adult female beaver (Castor canadensis) and colony fecundity.
90. University of Massachusetts.

Brunelle, J. 1986.
Characteristics of two adjacent beaver (Castor canadensis) populations in Quebec.
McGill University.

Busher, P. E. 1980.
The population dynamics and behavior of beavers on Sagehen Creek, California.
University of California.

Busher, P. E. 1980.
The population dynamics and behavior of beavers in the Sierra Nevada.
183:University of Nevada.

Busher, P. E., R. J. Warner and S. H. Jenkins. 1983.
Population density, colony composition, and local movements in two Sierra Nevada beaver populations.
Journal of Mammalogy. 64:314-318.

Busher, P. E. 1987.
Population parameters and family composition of beaver in California.
Journal of Mammalogy. 68:860-864.

Dieter, C. D. 1992.
Population Characteristics of Beavers in Eastern South-Dakota.
American Midland Naturalist. 128:191-196.
Biological characteristics of beavers (Castor canadensis) harvested during a spring hunting season in eastern South Dakota were determined. Age ratios in the sample showed 19.5% kits, 22.6% yearlings and 57.9% adults (2.5-3 years and older). The overall male: female ratio (1.24:1.00) was not significantly different from a 1: 1 ratio, but males (65%) dominated in the 4.5-5 year + age-class. Evidence of reproduction was found only in beavers 2.5-3 years of age or older. Adult females had a pregnancy rate of 62.5%. The mean number of embryos produced per breeding female was 4.0.

Fleming, M. W. 1977.
Induced sterility of the adult male beaver (*Castor canadensis*) and colony fecundity.
59. University of Massachusetts.

Fryxell, J. M. 2001.
Habitat suitability and source-sink dynamics of beavers.
Journal of Animal Ecology. 70:310-316.
1.Theory suggests that territorial species should share many of the same dynamical characteristics as metapopulations, including asynchronous local dynamics, potential for stochastic extinction of the population when rates of successful dispersal fall below mortality risk, and critical importance of the ratio of suitable to unsuitable habitat for long-term persistence. These propositions were tested on a population of beavers in Algonquin Provincial Park, Ontario, which has been continuously monitored over 11 years. 2. Results showed that the total population was considerly less variable than local abundance at 14 beaver colonies, due to asynchrony among local populations. This suggests that local ecological interactions were more important in determining year-to-year variation in beaver numbers than broad-scale environmental processes, such as weather. 3. Of the local colonies, 20% were never abandoned over 11 years, although there was considerable turnover among adults. Offspring production exceeded adult abundance at five source colonies, which did not quite compensate for negative net production at nine sink colonies. These observations were consistent with predictions of spatially structured models of territoriality incorporating local variation in habitat suitability. Mean colony size and probability of recurrence from year-to-year were associated with local food availability, indicating that trophic interactions were important in determining local population dynamics. 4. The beaver population in Algonquin declined steadily over the study period, however, suggesting that spatial and demographic processes were insufficient to stabilize abundance over time. This is consistent with predictions of spatially structured models of territoriality in which suitable and unsuitable habitats are interspersed. It is hypothesized that long-term decline in habitat suitability is induced by acceleration of woody plant succession due to selective foraging by beavers.

Gunson, J. R. 1970.
Dynamics of the beaver of Saskatchewan's northern forest.
University of Alberta.

Henry, D. B. and T. A. Bookhout. 1969.
Productivity of beavers in northeastern Ohio.
Journal of Wildlife Management. 33:927-932.
Productivity of beavers (Castor canadensis) from northeastern Ohio was calculated from analysis of 219 specimens (114 males, 105 females) collected in the 1966 and 1967 trapping seasons (Feb. 1-15). Beavers were aged by characteristics of eruption, closure of basal openings, and cementum layering of molar teeth. Seventy-four percent of breedingage females (1.5 years or older) had ovulated, but only 40 percent of 1.5-2-year-olds had ovulated. The mean ovulation rate for ovulating females was 4.3, and mean placental scar count was 3.8. Signs of implantation were present in 62 percent of breeding-age females. Mean ovulation rate, conception rate, and placental scar count increased to age 5.5-6 years. Estimated prenatal mortality was 11-16 percent. First-year trapping and natural mortality was calculated to be 41.6 percent. Estimated

rate of annual population increase, including prenatal and juvenile mortality, was 49 percent. On this basis, a harvest rate of 32 percent would maintain a stable beaver population.

Johnston, C. A. and R. J. Naiman. 1990.
Aquatic patch creation in relation to beaver population trends.
Ecology. 71:1617-1621.

Jonas, R. J. 1955.
A population and ecological study of the beaver, Castor canadensis, of Yellowstone Park.
University of Idaho.

Kafcas, E. N. 1987.
Census and exploitation of a discrete beaver population in Michigan.
1987:89. Central Michigan University.

Purpose was to develop a census technique, while evaluating beaver exploitation rates under 1979 and 1980 trapping regulations. The census technique related year-to-year changes in colony population size with numbers of colonies present, using the food cache method. Data concerning reproduction, population dynamics,. age, weight and movements, and habitat condition were collected to assess effects of trapping regulations.

Lyons, P. J. 1979.
Effects of induced sterility on reproduction and dispersal patterns in beaver colonies.
123. University of Massachusetts.

Lyons, P. J. 1979.
Productivity and population structure of western Massachusetts beavers.
Transactions of the Northeast Section of the Wildlife Society. 36:176-187.

McTaggart, S. T. and T. A. Nelson. 2003.
Composition and demographics of beaver (Castor canadensis) colonies in central Illinois.
American Midland Naturalist. 150:139-150.
Beavers (Castor canadensis) exhibit wide variations in colony composition and demographics over their broad geographic range, so regional population studies are important for sound management of this species. The objectives of this study were to investigate the: (1) size and sex-age composition of beaver colonies in Illinois, (2) reproductive potential of female beavers in these colonies and (3) efficacy of night-vision surveys versus removal trapping for estimating colony size. We harvested and aged 239 beavers (128 males: 111 females) during the 1999-2000 and 2000-2001 trapping seasons. The average colony contained 5.6 beavers. Family groups consisting of a breeding pair and at least 1 offspring composed 86% of these colonies; the other 14% consisted of only a breeding pair. Samples of beavers harvested by commercial trappers were skewed towards yearlings and 2-y olds relative to samples taken from trapped-out colonies. Fetal rates were 3.0, 3.4 and 4.2/female for yearlings, 2-y olds and older adults, respectively. In utero loss was estimated as 13%. Our estimates suggest that over 50% of kits die during the first 6 mo of life. We found no evidence that the presence of older offspring in a colony allowed parents to raise more kits. Night-vision surveys conducted 10 m downwind from the den for 2.5

h after sunset underestimated the size of colonies, accounting for only 55% of the beavers present.

Molini, J. J., R. A. Lancia, J. Bishir and H. E. Hodgdon. 1981.
A stochastic model of beaver population growth.
Proceedings of the Worldwide Furbearer Conference. 1215-1245.

Nordstrom, W. R. 1972.
Comparison of trapped and untrapped beaver populations in New Brunswick.
University of New Brunswick.

Osborn, D. J. 1949.
A study of age classes, reproduction and sex ratios of beaver in Wyoming.
University of Wyoming.

Parsons, G. R. 1975.
Effect of a 4-year closure of the trapping season for beaver in Eastern Warren County, New York.
New York Fish and Game Journal. 22:57-61.

Parsons, G. and M. Brown. 1978.
Effect of a four-year closure of trapping season for beaver in Fulton County.
New York Fish and Game Journal. 25:23-30.
Trapping for beaver in Fulton County was prohibited from 1969 to 1972, and the effects of the closure on the beaver population were evaluated. A substantial increase in beaver abundance insued, as evidenced by a calculated gain in the number of active colonies from 45 to 184. Beaver damage coplains also increased, plugging of road culverts being the principal type, but unil the number of colonies exceeded 150 the cost of servicing complaints was considered reasonable. It was concluded that an occupancy of 30 to 40 per cent of the potential colony sites would be desirable and that trapping may be permitted under regulations designed to maintain the beaver population at that level.

Parsons, G. and M. K. Brown. 1979.
Yearling reproduction in beaver as related to population density in a portion of New York.
Transactions of the Northeast Section of the Wildlife Society. 36:188-191.

Payne, N. F. 1976.
Trapline management and population biology of Newfoundland beaver.
36:4295. Utah State University.

Payne, N. F. 1984.
Mortality rates of beaver in Newfoundland [Castor canadensis].
Journal of Wildlife Management. 48:117-126 | 117. Wildlife Society.

Annual harvest mortality for sustained-yield management is described. Adult harvest mortality was compared with natural mortality, and the probability of compensatory natural mortality is discussed.

Payne, N. F. 1984.
Population dynamics of beaver in North America.
Acta Zoologica Fennica. 263-266.

Payne, N. F. 1989.
Population dynamics and harvest response of beaver.
Proceedings of the Fourth Eastern Wildlife Damage Control Conference. 127:127-132.
The author discusses beaver population control and various aspects of beaver life history. Habitat use, territoriality, colony size, dispersal, reproduction, mortality, and population response to harvesting are investigated in this paper.

Peterson, R. P. and N. F. Payne. 1986.
Productivity, size, age, and sex structure of nuisance beaver colonies in Wisconsin.
Journal of Wildlife Management. 50:265-268 | 265.

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.

Provost, E. E. 1958.
Studies on reproduction and population dynamics in beaver.
Washington State University.

"Data on sex and age composition of various populations (Washington) were compiled, together with observations on minimum breeding age and litter size. A general description of the gross morphology of the female urogenital system was given, and a tentative fetal growth curve, based on weight and hind foot length, was elaborated." Corpora lutea and corpora albicantia are easily recognized; within certain limitations both can be used as measures of reproductive performance, especially when correlations are established with fetal counts made just before parturition.

Rogers, J. R. 1950.
Beaver in southeastern Washington.
Washington State University.

Smith, D. W., D. R. Trauba, R. K. Anderson and R. O. e. a. Peterson. 1994.
Black bear predation on beavers on an island in Lake Superior.
American Midland Naturalist. 132:248-255 | 248.
Examines the predation of beaver colonies, Castor canadensis, by black bear cats, Ursus americanus, on two Lake Superior islands, Stockton Island and Outer Island in Wisconsin. Colonization of the islands by the beavers; Gut analysis of the bear cats; Predation of bearcats in relation to the availability of other food sources; Population dynamics of both populations.

Svendsen, G. E. 1980.
Population parameters and colony composition of beaver (*Castor canadensis*) in Southeast Ohio.
American Midland Naturalist. 104:47-56.

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

Taylor, D. 1970.
Growth, decline, and equilibrium in a beaver population at Sagehen Creek, California.
University of California.

Wright, J. P., W. S. C. Gurney, C. G. Jones and J. C. G. 2004.
Patch dynamics in a landscape modified by ecosystem engineers.
Oikos. 105:336-348.
Ecosystem engineers, organisms that modify the environment, have the potential to dramatically alter ecosystem structure and function at large spatial scales. The degree to which ecosystem engineering produces large-scale effects is, in part, dependent on the dynamics of the patches that engineers create. Here we develop a set of models that links the population dynamics of ecosystem engineers to the dynamics of the patches that they create. We show that the relative abundance of different patch types in an engineered landscape is dependent upon the production of successful colonists from engineered patches and the rate at which critical resources are depleted by engineers and then renewed. We also consider the effects of immigration from either outside the system or from engineers that are present in non-engineered patches, and the effects of engineers that can recolonize patches before they are fully recovered on the steady state distribution of different patch types. We use data collected on the population dynamics of a model engineer, the beaver, to estimate the per-patch production rate of new colonists, the decay rate of engineered patches, and the recovery rate of abandoned patches. We use these estimated parameters as a baseline to determine the effects of varying parameters on the distribution of different patch types. We suggest a number of hypotheses that derive from model predictions and that could serve as tests of the model. (Author)

<u>Relationships with invasive species</u>

Darbyshire, S. and L. Consaul. 1999.
Wildlife sometimes benefits from purple loosestrife.
Trail and Landscape. 33:181-184.
Although commonly thought of as merely a pest plant species, purple loosestrife is now suspected to be part of the diet of beaver on islands in the Ottawa River, Ontario, Canada. The authors indicate that this is the only reference they have found of beaver or other native wildlife consuming purple loosestrife. pcp.

Kimball, B. A. and K. R. Perry. 2008.
Manipulating beaver (Castor canadensis) feeding responses to invasive tamarisk (Tamarix spp.).
Journal of Chemical Ecology. 34:1050-1056.

To evaluate methods for promoting consumption of tamarisk plants by beavers (Castor canadensis), we determined the feeding responses by captive beavers to diets that contained tannins and sodium chloride (hereafter referred to as tamarisk diet). In two-choice tests, beavers consumed equivalent quantities of tamarisk diet and control diet. Treatment with polyethylene glycol and fructose did not increase beaver preferences for the tamarisk diet. When offered the choice of control diet and casein hydrolysate-treated control diet, beavers strongly avoided the latter, showing feeding deterring activity of casein hydrolysate. However, when tamarisk diet was the alternative to the deterrent treatment, beavers consumed similar quantities of the two diets. Finally, beaver foraging preferences for actual plant cuttings were assessed. Casein hydrolysate application to cuttings of black poplar (Populus nigra) and Scouler's willow (Salix scouleriana) reduced browsing of these highly preferred species and promoted a marked increase in browsing of tamarisk (Tamarix ramosissima). These results suggest that casein hydrolysate treatment of desirable riparian plant species such as Salix and Populus may promote beaver foraging of invasive tamarisk.

Lesica, P. and S. Miles. 2004.
Beavers indirectly enhance the growth of Russian olive and tamarisk along eastern Montana rivers.
Western North American Naturalist. 64:93-100.
Russian olive and tamarisk are introduced woody plants invading western North American riparian communities. Beavers can play an important role in structuring these communities by removing the dominant cottonwood trees. Our study explored the way in which beavers interact with cottonwood, Russian olive, and tamarisk along 4 rivers on the Great Plains of eastern Montana. We sampled cottonwood stands that supported populations of 1 or both exotic species, recording beaver damage and density in addition to size and age of cottonwood, Russian olive, and tamarisk. In stands where beaver had been present, they felled an average of 80% of cottonwood trees while rarely using Russian olive or tamarisk. Beaver foraging was apparent in nearly 90% of stands within 50 m of the river channel but only 21% of stands farther away, creating a sunny corridor along the river channel that may increase the invasive potential of Russian olive and tamarisk. Growth rates of both Russian olive and tamarisk were substantially higher where beavers had reduced the cottonwood canopy cover. Managers wishing to reintroduce beavers should consider the potential effect on invasive exotic plants.

Longcore, J. R., D. G. McAuley, G. W. Pendelton, C. R. Bennatti, T. M. Mingo and K. L. Stromborg. 2006.
Macroinvertebrate abundance, water chemistry, and wetland characteristics affect use of wetlands by avian species in Maine.
Hydrobiologia: the international journal on limnology and marine sciences. 567:143-167.
Our objective was to determine use by avian species (e.g., piscivores, marsh birds, waterfowl, selected passerines) of 29 wetlands in areas with low (< 200 mu eq l(-1)) acid-neutralizing capacity (ANC) in southeastern Maine. We documented bird, pair, and brood use during 1982-1984 and in 1982 we sampled 10 wetlands with a sweep net to collect invertebrates. We related mean numbers of invertebrates per wetland to water chemistry, basin characteristics, and avian use of different wetland types. Shallow, beaver (Castor canadensis)-created wetlands with the highest phosphorus levels and abundant and varied macrophyte assemblages supported greater densities of macroinvertebrates and numbers of duck broods (88.3% of all broods) in contrast to

deep, glacial type wetlands with sparse vegetation and lower invertebrate densities that supported fewer broods (11.7%). Low pH may have affected some acid-intolerant invertebrate taxa (i.e., Ephemeroptera), but high mean numbers of Insecta per wetland were recorded from wetlands with a pH of 5.51. Other Classes and Orders of invertebrates were more abundant on wetlands with pH > 5.51. All years combined use of wetlands by broods was greater on wetlands with pH <= 5.51 (77.4%) in contract to wetlands with pH > 5.51 that supported 21.8% of the broods. High mean brood density was associated with mean number of Insecta per wetland. For lentic wetlands created by beaver, those habitats contained vegetative structure and nutrients necessary to provide cover to support invertebrate populations that are prey of omnivore and insectivore species. The fishless status of a few wetlands may have affected use by some waterfowl species and obligate piscivores.

Northcott, T. H. 1972.
Water lilies as beaver food.
Oikos. 23:408-409.
NINE MILLION TONS OF SALT WERE USED IN 1970 TO CLEAN SNOW FROM HIGHWAYS. THESE QUANTITIES OF SALT HAVE ADVERSE EFFECTS ON PUBLIC DRINKING WATER SUPPLIES, WILDLIFE, VEGETATION, LAKES, AND RIVERS. A MIXTURE OF CALCIUM CHLORIDE AND SODIUM CHLORIDE LOWERS THE FREEZING POINT OF THE BRINE SOLUTION AND BREAKS THE BOND BETWEEN ICE AND ROAD. THE DANGER IS THAT HIGH CONCENTRATIONS OF SALTS MAY OVERLOAD DISPERSAL MECHANISMS. IT IS ESTIMATED THAT 25 TO 50 PER CENT OF THE SALT INFILTRATES TO THE GROUNDWATER. HIGH RUNOFF CONTAMINATES MANY SHALLOW WELLS AND CAN ALSO AFFECT WILDLIFE BY DISTURBING BODY PROCESSES. SALT IN WATER SUPPLIES MAY BE HARMFUL TO PEOPLE WITH HEART DISEASE OR THOSE ON LOW SALT DIETS. SALINE SOIL WATER WILL INHIBIT THE PLANTS INTAKE OF WATER AND MAKE SOIL LESS PERMEABLE. SUBSTANTIAL LOSSES OF ROADSIDE TREES HAVE OCCURRED. SALT MAY ALSO DISRUPT THE VERTICAL MIXING IN LAKES AND PONDS THROUGH DENSITY STRATIFICATION AND DEGRADE FISH ENVIRONMENTS.

Parker, J. D., C. C. Caudill and M. E. Hay. 2007.
Beaver herbivory on aquatic plants.
Oecologia. 151:616-625.
Herbivores have strong impacts on marine and terrestrial plant communities, but their impact is less well studied in benthic freshwater systems. For example, North American beavers (Castor canadensis) eat both woody and non-woody plants and focus almost exclusively on the latter in summer months, yet their impacts on non-woody plants are generally attributed to ecosystem engineering rather than herbivory. Here, we excluded beavers from areas of two beaver wetlands for over 2 years and demonstrated that beaver herbivory reduced aquatic plant biomass by 60%, plant litter by 75%, and dramatically shifted plant species composition. The perennial forb lizard's tail (Saururus cernutts) comprised less than 5% of plant biomass in areas open to beaver grazing but greater than 50% of plant biomass in beaver exclusions. This shift was likely due to direct herbivory, as beavers preferentially consumed lizard's tail over other plants in a field feeding assay. Beaver herbivory also reduced the abundance of the invasive aquatic plant Myriophyllum aquaticum by nearly 90%, consistent with recent evidence that native generalist

herbivores provide biotic resistance against exotic plant invasions. Beaver herbivory also had indirect effects on plant interactions in this community. The palatable plant lizard's tail was 3 times more frequent and 10 times more abundant inside woolgrass (Scirpus cyperinus) tussocks than in spatially paired locations lacking tussocks. When the protective foliage of the woolgrass was removed without exclusion cages, beavers consumed nearly half of the lizard's tail leaves within 2 weeks. In contrast, leaf abundance increased by 73-93% in the treatments retaining woolgrass or protected by a cage. Thus, woolgrass tussocks were as effective as cages at excluding beaver foraging and provided lizard's tail plants an associational refuge from beaver herbivory. These results suggest that beaver herbivory has strong direct and indirect impacts on populations and communities of herbaceous aquatic plants and extends the consequences of beaver activities beyond ecosystem engineering.

Perkins, T. E. and M. V. Wilson. 2005.
The impacts of Phalaris arundinacea (reed canarygrass) invasion on wetland plant richness in the Oregon Coast Range, USA depend on beavers.
Biological Conservation. 124:291-295.
Invasive plants can threaten diversity and ecosystem function. We examined the relationship between the invasive Phalaris arundinacea (reed canarygrass) and species richness in beaver wetlands in Oregon, USA. Four basins (drainages) were chosen and three sites each of beaver impoundments, unimpounded areas and areas upstream of debris jams were randomly chosen in each basin for further study (n = 36). Analysis of covariance (ANCOVA) showed that the relationship between Phalaris and species richness differed significantly (p = 0.01) by site type. Dam sites (beaver impoundments) exhibited a strong inverse relationship between Phalaris and species richness (bD = -0.15), with one species lost for each 7% increase in Phalaris cover. In contrast, there was essentially no relationship between Phalaris cover and species richness in jam sites (debris jam impoundments formed by flooding; bJ = +0.01) and unimpounded sites (bU = -0.03). The cycle of beaver impoundment and abandonment both disrupts the native community and provides an ideal environment for Phalaris, which once established tends to exclude development of herbaceous communities and limits species richness. Because beaver wetlands are a dominant wetland type in the Coast Range, Phalaris invasion presents a real threat to landscape heterogeneity and ecosystem function in the region. [copyright] 2005 Elsevier Ltd. All rights reserved.

Relationships with Salmonid species

Archer, D. L. 1972.
Fisheries investigations in lakes and streams: Evaluation of stream improvement work.

WHAT STARTED AS A PROJECT TO EVALUATE STREAM IMPROVEMENT STRUCTURES, TURNED INTO GOOD DOCUMENTATION OF WHAT THE EFFECTS OF ROAD BUILDING AND INVASION OF BEAVERS HAS ON A NATURAL TROUT STREAM.

Bertolo, A., P. Magnan and M. Plante. 2008.
Linking the occurrence of brook trout with isolation and extinction in small boreal shield lakes.
Freshwater Biology. 53:304-321.

1. We surveyed 62 Canadian Shield lakes (< 50 ha) to determine the relationship between factors related to isolation and extinction and the occurrence of brook trout (BT) (Salvelinus fontinalis), for which local extinctions have been documented over the last century in half of the lakes. 2. Logistic regression and information-theoretic model selection were used to determine the importance for the occupancy of BT of (i) isolation factors (degree of lake connectivity and the proximity of source populations of BT in neighbouring bodies of water) and (ii) extinction factors (lake morphometry and trophic status, as proxies of the risk of lake anoxia; predation and competition; and flooding caused by beaver (Castor canadensis) dams, which could potentially increase the risk of anoxia). 3. Isolation factors were the best predictors of the absence of BT in these lakes. Among extinction factors, only the impact of beaver dams (as measured by an index of increased water level and mortality of shrubs and trees in the littoral zone) improved model fits. Beaver dams were present at the outlets of all study lakes, but extensive mortality of riparian trees and shrubs was more common in lakes where BT populations were extinct. 4. Taken together, these results suggest that recolonization is a major factor determining the occurrence of BT while flooding caused by beaver dams might contribute to BT extinction by increasing the likelihood of winterkill in these small lakes.

Call, M. W. 1966.
Beaver-trout relationship study: Beaver pond ecology and beaver-trout relationships in southeastern Wyoming.

Work performed in Medicine Bow National Forest Characteristics of beaver dams and their influence on trout in the beaver ponds are discussed. Interspecies relationships concern only the influence of beaver ponds on trout. Other than that there is no interaction.

Call, M. W. 1970.
Beaver pond ecology and beaver-trout relationships in southeastern Wyoming.
University of Wyoming.

Lindstrom, J. W. and W. A. Hubert. 2004.
Ice processes affect habitat use and movements of adult cutthroat trout and brook trout in a Wyoming foothills stream.
North American Journal of Fisheries Management. 24:1341-1352.
Habitat use and movements of 25 adult cutthroat trout Oncorhynchus clarkii and 25 adult brook trout Salvelinus fontinalis from fall through winter 2002-2003 were assessed by means of radiotelemetry in a 7-km reach of a Rocky Mountains foothills stream. Temporal dynamics of winter habitat conditions were evaluated by regularly measuring the features of 30 pools and 5 beaver Castor canadensis ponds in the study reach. Groundwater inputs at three locations raised mean daily water temperatures in the stream channel during winter to 0.2-0.6 degrees Celsius and kept at least 250 m of the downstream channel free of ice, but the lack of surface ice further downstream led to the occurrence of frazil ice and anchor ice in pools and unstable habitat conditions for trout. Pools in segments that were not affected by groundwater inputs and beaver ponds tended to be stable and snow accumulated on the surface ice. Pools throughout the study reach tended to become more stable as snow accumulated. Both cutthroat trout and brook trout selected beaver ponds as winter progressed but tended to use lateral scour pools in proportion to their availability. Tagged fish not in beaver ponds selected lateral scour pools that were deeper

than average and stable during winter. Movement frequencies by tagged fish decreased from fall through winter, but some individuals of both species moved during winter. Ice processes affected both the habitat use and movement patterns of cutthroat trout and brook trout in this foothills stream.

McDowell, R. A. 1975.
Fishery management investigations. Study of the Pole Mountain Fishery: Beaver pond, artificial impoundment and stream investigations.

McRae, G. and C. J. Edwards. 1994.
Thermal characteristics of Wisconsin headwater streams occupied by beaver: Implications for brook trout habitat.
American Fisheries Society. Transactions.

Mitchell, S. C. and R. A. Cunjak. 2007.
Stream flow, salmon and beaver dams: roles in the structuring of stream fish communities within an anadromous salmon dominated stream.
Journal of Animal Ecology.
The current paradigm of fish community distribution is one of a downstream increase in species richness by addition, but this concept is based on a small number of streams from the mid-west and southern United States, which are dominated by cyprinids. Further, the measure of species richness traditionally used, without including evenness, may not be providing an accurate reflection of the fish community. We hypothesize that in streams dominated by anadromous salmonids, fish community diversity will be affected by the presence of the anadromous species, and therefore be influenced by those factors affecting the salmonid population. Catamaran Brook, New Brunswick, Canada, provides a long-term data set to evaluate fish community diversity upstream and downstream of an obstruction (North American beaver Castor canadensis dam complex), which affects distribution of Atlantic salmon Salmo salar. The Shannon Weiner diversity index and community evenness were calculated for sample sites distributed throughout the brook and over 15 years. Fish community diversity was greatest upstream of the beaver dams and in the absence of Atlantic salmon. The salmon appear to depress the evenness of the community but do not affect species richness. The community upstream of the beaver dams changes due to replacement of slimy sculpin Cottus cognatus by salmon, rather than addition, when access is provided. Within Catamaran Brook, location of beaver dams and autumn streamflow interact to govern adult Atlantic salmon spawner distribution, which then dictates juvenile production and effects on fish community. These communities in an anadromous Atlantic salmon dominated stream do not follow the species richness gradient pattern shown in cyprinid-dominated streams and an alternative model for stream fish community distribution in streams dominated by anadromous salmonids is presented. This alternative model suggests that community distribution may be a function of semipermeable obstructions, streamflow and the distribution of the anadromous species affecting resident stream fish species richness, evenness, biomass and production.

Rupp, R. S. 1954.
Beaver-trout relationship in the headwaters of Sunkhaze Stream, Maine.
American Fisheries Society. Transactions. 84:75-85.

Sigourney, D. B., B. H. Letcher and R. A. Cunjak. 2006.
Influence of beaver activity on summer growth and condition of age-2 Atlantic salmon parr.
American Fisheries Society. Transactions. 135:1068-1075.
The activity of beavers Castor canadensis in freshwater environments can have considerable localized impacts on the physical and biological components of riparian ecosystems. By changing the habitat of a stream, beaver dams can cause spatial variation in growth opportunity that may have direct consequences for the growth of resident fish. In a small stream in eastern Canada, we studied the effects of an ephemeral beaver pond on the growth and maturity of age-2 Atlantic salmon Salmo salar parr tagged with passive integrated transponder tags. Water temperature remained relatively uniform throughout the study site. We found very little movement of recaptured fish in the study site. Fish that were recaptured in the beaver pond displayed faster summer growth rates in both length and mass than fish that were recaptured immediately above or below the pond. We also found that Parr in the pond maintained relatively high condition factors, whereas fish above and below the pond appeared to decrease in condition factor throughout the summer. In addition to growth, the maturation rates of age-2 males were higher above the dam than below. This study demonstrates the effect a beaver dam can have on individual growth rates. By influencing growth during sensitive periods, the beaver pond may also influence individual life history pathways. This information could be an important component in ecosystem models that predict the effect of beaver population dynamics on the growth of individual salmonids at the landscape scale.

Snyder, C. D., J. A. Young and B. M. Stout III. 2006.
Aquatic habitats of Canaan Valley, West Virginia: Diversity and environmental threats.
Northeastern Naturalist. 13:333-352.
We conducted surveys of aquatic habitats during the spring and summer of 1995 in Canaan Valley, WV, to describe the diversity of aquatic habitats in the valley and identify issues that may threaten the viability of aquatic species. We assessed physical habitat and water chemistry of 126 ponds and 82 stream sites, and related habitat characteristics to landscape variables such as geology and terrain. Based on our analyses, we found two issues likely to affect the viability of aquatic populations in the valley. The first issue was acid rain and the extent to which it potentially limits the distribution of aquatic and semi-aquatic species, particularly in headwater portions of the watershed. We estimate that nearly 46%, or 56 kilometers of stream, had pH levels that would not support survival and reproduction of Salvelinuw fontinalis (brook trout), one of the most acid-tolerant fishes in the eastern US. The second issue was the influence of Castor canadensis (beaver) activity. In the Canaan Valley State Park portion of the valley, beaver have transformed 4.7 kilometers of stream (approximately 17% of the total) to pond habitat through their dam building. This has resulted in an increase in pond habitat, a decrease in stream habitat, and a fragmented stream network (i.e., beaver ponds dispersed among stream reaches). In addition, beaver have eliminated an undetermined amount of forested riparian area through their foraging activities. Depending on the perspective, beaver-mediated changes can be viewed as positive or negative. Increases in pond habitat may increase habitat heterogeneity with consequent increases in biological diversity. In contrast, flooding associated with beaver activity may eliminate lowland wetlands and associated species, create barriers to fish dispersal, and possibly contribute to low dissolved oxygen levels in the Blackwater River. We recommend that future management strategies for the wildlife refuge be viewed in the context of these two issues,

and that the responses of multiple assemblages be incorporated in the design of refuge management plans.

Taylor, G. B., J. A. Barnes and D. H. Van Lear. 1994.
Impacts of beaver (Castor canadensis carolinensis) on riparian ecosystems, water quality, and trout habitat in the Chauga River Drainage.
Society of American Foresters National Convention Proceedings. 1993:534-535.

Winkle, P. L., W. A. Hubert and F. J. Rahel. 1990.
Relations between brook trout standing stocks and habitat features in beaver ponds in southeastern Wyoming.
North American Journal of Fisheries Management. 10:72-79.

Relocation (translocation)

Harris, H. T. 1991.
Habitat use by dispersing and transplanted beavers in western Montana.
40:Univ. of Montana.

Lay, D. W. 1944.
Beaver, specialist.
Texas Fish & Game. 2:4-5.
General account of life history and dam-building proclivities. Trapping in some localities has been decimating and remedial legislation has been enacted. Results of transplanting; very few of the animals stayed where they were released; some travelled 150 miles or more.

McKinstry, M. C. and S. H. Anderson. 2002.
Survival, fates, and success of transplanted beavers, Castor canadensis, in Wyoming.
Canadian Field-Naturalist. 116:60-68 | 60.
Beaver (Castor canadensis) through their dam building activities, store water, trap sediment, subirrigate vegetation, and subsequently improve habitat for fish, wildlife, and livestock. Many landowners realize the benefits that Beaver can bring to a riparian area and are interested in using them to improve this habitat. From 1994 to 1999 we trapped and relocated 234 Beaver to 14 areas throughout Wyoming to improve riparian habitat and create natural wetlands. We attached radio transmitters to 114 Beaver and subsequently determined movements and mortality of released Beaver, and the overall success of our releases. Mortality and emigration (including transmitter failure) accounted for the loss of 30% and 51%, respectively, of telemetered Beaver within 6 months of release. Kaplan-Meier survival estimates were 0.49 (SE=0.068) for 180 days and 0.433 (SE=0.084) for 360 days, and did not differ significantly between age classes. On average, 17 Beaver were transplanted to each release site, and at 11 locations, in an attempt to augment single Beaver that had become established and increase transplant success, we transplanted Beaver in two or more years. Success of an individual Beaver's relocation was unrelated to any of the variables we tested, although 2-3.5 year-old Beaver had higher average success (measured in days of occupancy at the release site) than older animals. Animals <2 years old had 100% mortality and emigration losses within 6 months of release. High predation and mortality rates of our released Beaver may be due to habitat (our streams were shallow with

no ponds and provided little protection) and extensive predator communities. We established Beaver at 13/14 of our release sites and they eventually reproduced. Our results show that Beaver can be relocated successfully but losses from mortality and emigration need to be considered and planned for.

McKinstry, M. C. and S. H. Anderson. 2003.
Survival, fates, and success of transplanted beavers (Castor canadensis) in Wyoming.
Journal of Wildlife Rehabilitation. 26:17-23.
[unedited] Beaver (Castor canadensis), through their dam building activities, alter riparian-stream ecosystems, and many landowners recognize these benefits. From 1994-1999, we trapped and relocated 234 beaver to 14 areas throughout Wyoming to improve riparian habitat and create natural wetlands. Radio transmitters were attached to 114 beaver. Mortality and emigration (included transmitter failure) accounted for the loss of 30% and 51%, respectively, of telemetered beaver within six months of release. On average, 17 beaver were transplanted to each release site; at 11 locations, in an attempt to augment single beaver that had become established and increase transplant success, we transplanted beaver in two or more years. Success of an individual beaver's relocation was unrelated to any of the variables tested. High predation and mortality rates of released beaver may be due to habitat and extensive predator communities. Beaver were established at 13/14 of our release sites and they eventually reproduced.

Reproduction

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

Brenner, F. J. 1964.
Reproduction of the beaver in Crawford County, Pennsylvania.
Journal of Wildlife Management. 28:743-747.
Data were collected on weight, pelt size, and the reproductive tracts of beavers (Castor canadensis) in Crawford County, Pennsylvania, during the trapping season. The age at which beavers attain sexual maturity appears to be 2 years. Embryos were found only in females classed as 2-year-olds and older. In a histological examination of the testes, spermatozoa were found only in 2-year-old or older males; these individuals also had an increase in sudanophilic activity, which indicated an increase in testosterone production over yearling animals. The number of embryos varied from one to nine with a mean of 5.50 per pregnant female. The potential litter size was 5.04 embryos per female of those that were pregnant or had been pregnant before complete or partial resorption occurred. Resorption occurred in 16.7 percent of the pregnant females examined. These resorptions reduced the potential population of young by 6.9 percent. All resorptions occurred in 2-year-old females which had bred for the first time. The adult females produced larger potential litters than did the 2-year-old animals. The breeding season in Crawford County extended from the last of January through February, as calculated from the age of the embryos examined during the trapping season and the occurrence of scent mounds.

Brooks, R. P. 1977.
Induced sterility of the adult female beaver (Castor canadensis) and colony fecundity.
90. University of Massachusetts.

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 | 568.

Brophy, T. R. and C. H. Ernst. 1999.
Reproduction and health of a beaver (Castor canadensis) population in Prince William County, Virginia.
Maryland Naturalist. 43:1-6.
Reproduction and health were studied in a beaver (Castor canadensis) population from Prince William County, Virginia during 1998. Copulating beavers were observed in Quantico Creek at Prince William Forest Park on 22 January. Seven females from Quantico Marine Base were trapped between January and May, sacrificed, and dissected. Those reproductively active weighed over 39 pounds (17.7 kg) and were trapped before 1 March. Mean litter size based on counts of corpora lutea was 4.80 young (3-7); however, litter size based on the number of embryos present was only 2.75 (1-3), comparable to most others reported in the literature. Five of the seven dissected females had prime pelts, one an average pelt, and one a poor quality pelt. Subcutaneous fat deposits and those at the base of the tail were moderate to high in all females. Four contained moderate mesenteric deposits, while three had low to no mesenteric fat present. No abnormalities were found in the heart, lungs, liver, kidneys, or bladder. Four females had suffered wounds to either the tail and/or body, possible from male courtship. The females harbored two of the most common beaver helminths: the stomach nematode, Travassosius americanus (100% incidence) and the cecal trematode, Stichorchis subtriquetrus (86% incidence). Compared to other reported studies, these worm burdens were moderate to average.

Coutu, D. J. 1961.
A study of the reproductive rate of beaver in Maine.
University of Maine.

A study to determine the rate of reproduction of beaver in Maine for the years 1959 and 1960. Objectives were to determine any changes in the overall rate of reproduction since 1947-1950, to investigate possible differences in reproduction between beaver of different climatic zones and to compare the reproductive rate between large and small beaver. Investigations show that the reproductive rate in Maine beaver has not changed statistically in the past decade. Beaver of the Central Zone produced significantly more young than did those of the Northern Zone. Measurable differences occurred between large and small beaver.

Danilov, P. I. and V. Y. A. Danshiev. 1983.
The state of populations and ecology characteristics of European (Castor fiber L.) and Canadian (Castor canadensis Kuhl.) beavers in the Northwestern USSR.
Acta Zoologica Fennica. 174:95-97.

Deroos, R. M. 1958.

The reproductive cycle of the beaver.
Utah State University.

Fleming, M. W. 1977.
Induced sterility of the adult male beaver (*Castor canadensis*) and colony fecundity.
59. University of Massachusetts.

Gordon, K. L. and D. H. Arner. 1976.
Preliminary Study Using Chemosterilants for Control of Nuisance Beaver.
30:463-465.
Objective was to determine the effectiveness of two orally active estrogen compounds in reducing fertility in beaver. The chemosterilants used were 17 ethynylestradiol-3-cyclopentylether and Searle Laboratories SC-24674.

Hallet, D. L. and D. W. Erickson. 1980.
Beaver (*Castor candensis*).
USDI Fish and Wildlife Service, Resource Publication. 133:99-105.

Harper, W. R. 1968.
Chemosterilant assessment for beaver.
Colorado State University.

Jenkins, S. H. and P. E. Busher. 1979.
Castor canadensis.
Mammalian Species. 120:1-8.

Kafcas, E. N. 1987.
Census and exploitation of a discrete beaver population in Michigan.
1987:89. Central Michigan University.

Purpose was to develop a census technique, while evaluating beaver exploitation rates under 1979 and 1980 trapping regulations. The census technique related year-to-year changes in colony population size with numbers of colonies present, using the food cache method. Data concerning reproduction, population dynamics,. age, weight and movements, and habitat condition were collected to assess effects of trapping regulations.

Kennelly, J. J. and P. J. Lyons. 1983.
Evaluation of induced sterility for beaver (Castor canadensis) management problems.

Lizotte, R. E., Jr. 1994.
Reproductive biology of beaver (Castor canadensis) at Old Hickory Lake in middle Tennessee.
Tennessee Academy of Science. Journal. 69:23-26.

Longley, W. H. and J. B. Moyle. 1963.
The beaver in Minnesota.

This bulletin is replete with information on history, economics, natural history and management of the beaver. Much of the information is based on data collected in Minn., but full use is also made of the literature. There are 77 titles listed in the bibliography. The appendix contains 2 articles from other publications: A guide to beaver trapping and pelting by Keith G. Hay and William H. Rutherford, and Grading of beaver pelts and manufacture of fur coats by Wendell G. Swank.

Lyons, P. J. 1979.
Effects of induced sterility on reproduction and dispersal patterns in beaver colonies.
123. University of Massachusetts.

Lyons, P. J. 1979.
Productivity and population structure of western Massachusetts beavers.
Transactions of the Northeast Section of the Wildlife Society. 36:176-187.

McKinstry, M. C. and S. H. Anderson. 2002.
Survival, fates, and success of transplanted beavers, Castor canadensis, in Wyoming.
Canadian Field-Naturalist. 116:60-68 | 60.
Beaver (Castor canadensis) through their dam building activities, store water, trap sediment, subirrigate vegetation, and subsequently improve habitat for fish, wildlife, and livestock. Many landowners realize the benefits that Beaver can bring to a riparian area and are interested in using them to improve this habitat. From 1994 to 1999 we trapped and relocated 234 Beaver to 14 areas throughout Wyoming to improve riparian habitat and create natural wetlands. We attached radio transmitters to 114 Beaver and subsequently determined movements and mortality of released Beaver, and the overall success of our releases. Mortality and emigration (including transmitter failure) accounted for the loss of 30% and 51%, respectively, of telemetered Beaver within 6 months of release. Kaplan-Meier survival estimates were 0.49 (SE=0.068) for 180 days and 0.433 (SE=0.084) for 360 days, and did not differ significantly between age classes. On average, 17 Beaver were transplanted to each release site, and at 11 locations, in an attempt to augment single Beaver that had become established and increase transplant success, we transplanted Beaver in two or more years. Success of an individual Beaver's relocation was unrelated to any of the variables we tested, although 2-3.5 year-old Beaver had higher average success (measured in days of occupancy at the release site) than older animals. Animals <2 years old had 100% mortality and emigration losses within 6 months of release. High predation and mortality rates of our released Beaver may be due to habitat (our streams were shallow with no ponds and provided little protection) and extensive predator communities. We established Beaver at 13/14 of our release sites and they eventually reproduced. Our results show that Beaver can be relocated successfully but losses from mortality and emigration need to be considered and planned for.

McTaggart, S. T. and T. A. Nelson. 2003.
Composition and demographics of beaver (Castor canadensis) colonies in central Illinois.
American Midland Naturalist. 150:139-150.
Beavers (Castor canadensis) exhibit wide variations in colony composition and demographics over their broad geographic range, so regional population studies are important for sound management of this species. The objectives of this study were to investigate the: (1) size and sex-

age composition of beaver colonies in Illinois, (2) reproductive potential of female beavers in these colonies and (3) efficacy of night-vision surveys versus removal trapping for estimating colony size. We harvested and aged 239 beavers (128 males: 111 females) during the 1999-2000 and 2000-2001 trapping seasons. The average colony contained 5.6 beavers. Family groups consisting of a breeding pair and at least 1 offspring composed 86% of these colonies; the other 14% consisted of only a breeding pair. Samples of beavers harvested by commercial trappers were skewed towards yearlings and 2-y olds relative to samples taken from trapped-out colonies. Fetal rates were 3.0, 3.4 and 4.2/female for yearlings, 2-y olds and older adults, respectively. In utero loss was estimated as 13%. Our estimates suggest that over 50% of kits die during the first 6 mo of life. We found no evidence that the presence of older offspring in a colony allowed parents to raise more kits. Night-vision surveys conducted 10 m downwind from the den for 2.5 h after sunset underestimated the size of colonies, accounting for only 55% of the beavers present.

Newberry, D. W. 1973.
Special wildlife investigations: Contributions toward a bibliography on California furbearers.

Osborn, D. J. 1949.
A study of age classes, reproduction and sex ratios of beaver in Wyoming.
University of Wyoming.

Parsons, G. and M. K. Brown. 1979.
Yearling reproduction in beaver as related to population density in a portion of New York.
Transactions of the Northeast Section of the Wildlife Society. 36:188-191.

Patenaude, R. P. and J. Bovet. 1983.
Parturition and related behavior in wild American beavers (Castor canadensis).
Zeitschrift fuer Saeugetierkunde. 48:136-145.

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

Payne, N. F. 1989.
Population dynamics and harvest response of beaver.
Proceedings of the Fourth Eastern Wildlife Damage Control Conference. 127:127-132.
The author discusses beaver population control and various aspects of beaver life history. Habitat use, territoriality, colony size, dispersal, reproduction, mortality, and population response to harvesting are investigated in this paper.

Pearson, A. M. 1960.
A study of the growth and reproduction of the beaver, Castor canadensis, Kuh, correlated with the quality and quantity of some habitat factors.
University of British Columbia.

Provost, E. E. 1958.

Studies on reproduction and population dynamics in beaver.
Washington State University.

"Data on sex and age composition of various populations (Washington) were compiled, together with observations on minimum breeding age and litter size. A general description of the gross morphology of the female urogenital system was given, and a tentative fetal growth curve, based on weight and hind foot length, was elaborated." Corpora lutea and corpora albicantia are easily recognized; within certain limitations both can be used as measures of reproductive performance, especially when correlations are established with fetal counts made just before parturition.

Ruusila, V., A. Ermala, H. Hyv„rinen and H. H. 2000.
Costs of reproduction in introduced female Canadian beavers (Castor canadensis).
Journal of Zoology. 252:79-82.
In iteroparous organisms, maximum lifetime reproductive success is achieved through multiple successful breeding attempts. Therefore one of an individual's major life-history decisions is the allocation of resources between current and future reproduction. The authors studied the reproduction of foetuses in the introduced female Canadian beaver Castor canadensis in Finland in 1992-1993. The number of foetuses produced in 1993 was negatively correlated with the number produced in the previous year, irrespective of female age. Females that bred only in 1993 tended to produce more foetuses in that year than females that had reproduced in both years. However, the total number of foetuses produced was higher in females that had young in both years, stressing the importance of multiple breeding attempts in maximizing lifetime reproductive success. Despite the small size of the founder population in Finland, mean litter size and pregnancy rates were not different from North American populations.

Thomason III, W. B. 1978.
Seasonal patterns of beaver reproduction in east-central Mississippi.
Mississippi State University.

Wheatley, M. 1993.
Report of two pregnant beavers, Castor canadensis, at one beaver lodge.
Canadian Field-Naturalist. 107:103.

Wigley, T. B., T. H. Roberts and D. H. Arner. 1984.
Methods of determining litter size in beaver.
38:197-200.
Objective was to determine the reliability of litter size estimates of beaver based on numbers of corpora lutea, corpora albicantia, and placental scars by comparing them to known litter size determined by fetus counts.

Zeckmeister, M. T. and N. F. Payne. 1998.
Effects of trapping on colony density, structure, and reproduction of a beaver population unexploited for 19 years.
Wisconsin Academy of Sciences, Arts and Letters. Transactions. 86:281-291.
The authors studied the influence of trapping on colony density, structure, and reproduction of a beaver population that had not been trapped in 19 years. After 19 years of being closed to

trapping, the beaver colony density in the Sandhill Wildlife Area of Wisconsin was 1.30 colonies/km2 compared to an adjacent trapped area which had a density of 0.42 colonies/km2. A winter harvest of 3.9 beavers/colony in 1981 resulted in a 21% decline in active colonies in 1982. The harvest of 3.2 beavers/colony in 1982 resulted in a 53% decline in 1983. slj.

Restoration

Albert, S. 1999.
The beaver and the flycatcher.
Endangered Species Bulletin. 24:16-17.
The author discusses the status of the North American beaver and the southwestern willow flycatcher. In a semi-arid region the beaver provides many benefits to other species. The flow of water is slowed down by the construction of beaver dam and this, in turn, allows the sediment to drop out and the water to percolate into the soil thus maintaining a high water table that will contribute to greater abundance and diversity of riparian vegetation and wildlife. In the 18th and 19th centuries the North American beaver populations started declining and the southwestern willow flycatcher species became endangered. With the help of beavers the Zuni Reservation in the semi-arid high desert of the Colorado Plateau began restoring riparian and wetland habitats. Small numbers of beavers were moved to streams containing abundant food. As the stream channel was incised it did not hold water year round. Existence of beavers in the area began to make a difference. The beaver dams helped slow down the flow of water and sediment to drop out. The water table began spreading over a wider area and thicker, lush, riparian vegetation began to be established. With better vegetation and habitat wildlife also improved in the riparian areas. With the open water pairs of flycatchers started establishing territories near the active beaver dams. The farmers who had initially complained about the beaver program benefited from the beaver dam water during the 1996 drought period.

Apple, L. L., B. H. Smith, J. D. Dunder and B. W. Baker. 1984.
The Use of Beavers for Riparian/Aquatic Habitat Restoration of Cold Desert, Gully-Cut Stream Systems in Southwestern Wyoming.

Apple, L. L. 1985.
Riparian habitat restoration and beavers.
120:489-490.

Baker, B. W., D. L. Hawksworth and J. G. Graham. 1992.
Wildlife Habitat Response to Riparian Restoration on the Douglas Creek Watershed.

Progress and preliminary results are reported following two years of study to evaluate wildlife and habitat response to varied livestock grazing, channel morphology, and beaver abundance in the Douglas Creek watershed. The performance the yellow warbler and beaver habitat suitability index (HSI) models.

Baker, B. W. 2003.
Beaver (Castor canadensis) in heavily browsed environments.
Lutra. 46:173-181.

Beaver (Castor canadensis) populations have declined or failed to recover in heavily browsed environments. I suggest that intense browsing by livestock or ungulates can disrupt beaver-willow (Salix spp.) mutualisms that likely evolved under relatively low herbivory in a more predator-rich environment, and that this interaction may explain beaver and willow declines. Field experiments in Rocky Mountain National Park, Colorado, USA, found the interaction of beaver and elk (Cervus elaphus) herbivory suppressed compensatory growth in willow. Intense elk browsing of simulated beaver-cut willow produced plants which were small and hedged with a high percentage of dead stems, whereas protected plants were large and highly branched with a low percentage of dead stems. Evaluation of a winter food cache showed beaver had selected woody stems with a lower percentage of leaders browsed by elk. A lack of willow stems suitable as winter beaver food may cause beaver populations to decline, creating a negative feedback mechanism for beaver and willow. In contrast, if browsing by livestock or ungulates can be controlled, and beaver can disperse from a nearby source population, then beaver may build dams in marginal habitat which will benefit willow and cause a positive riparian response that restores proper function to degraded habitat. In a shrub-steppe riparian ecosystem of northwestern Colorado, USA, rest from overgrazing of livestock released herbaceous vegetation initiating restoration of a beaver-willow community. Thus, competition from livestock or ungulates can cause beaver and willow to decline and can prevent their restoration in heavily browsed riparian environments, but beaver and willow populations can recover under proper grazing management.

Baker, B. W., H. C. Ducharme, D. C. S. Mitchell, T. R. Stanley and H. R. Peinetti. 2005.
Interaction of beaver and elk herbivory reduces standing crop of willow.
Ecological Applications. 15:110-118.
Populations of beaver and willow have not thrived in riparian environments that are heavily browsed by livestock or ungulates, such as elk. The interaction of beaver and elk herbivory may be an important mechanism underlying beaver and willow declines in this competitive environment. We conducted a field experiment that compared the standing crop of willow three years after simulated beaver cutting on paired plants with and without intense elk browsing ([approximately]85% utilization rate). Simulated beaver cutting with intense elk browsing produced willow that was small (biomass and diameter) and short, with far fewer, but longer, shoots and a higher percentage of dead biomass. In contrast, simulated beaver cutting without elk browsing produced willow that was large, tall, and leafy, with many more, but shorter, shoots (highly branched) and a lower percentage of dead biomass. Total stem biomass after three years was 10 times greater on unbrowsed plants than on browsed plants. Unbrowsed plants recovered 84% of their pre-cut biomass after only two growing seasons, whereas browsed plants recovered only 6%. Thus, the interaction of beaver cutting and elk browsing strongly suppressed the standing crop of willow. We predict that a lack of willow suitable as winter food for beaver can cause beaver populations to decline, creating a feedback mechanism that reduces beaver and willow populations. Thus, intense herbivory by ungulates or livestock can disrupt beaver-willow mutualisms that naturally occur in less competitive environments.

Bilyeu, D. M., D. J. Cooper and N. T. Hobbs. 2008.
Water tables constrain height recovery of willow on Yellowstone's northern range.
Ecological Applications. 18:80-92.

The article presents a factorial field experiment to determine willow's responses to browsing and to height of water tables within the northern range in Yellowstone National Park in the U.S. The authors observed that after four years of protection from elk browsing, willows with ambient water tables averaged only 106 centimeters in height, with negligible height gain in two of the three study species. Result of the study indicates that water availability mediates the rate of willow height gain and may determine whether willows grow tall enough to escape the browse zone of elk.

Brown, A. G. 2002.
Learning from the past: Palaeohydrology and palaeoecology.
Freshwater Biology. 47:817-829.
Attempts to increase European biodiversity by restoring rivers and floodplains are based on inadequate data on natural systems. This is particularly the case for NW European rivers because all catchments have been impacted by agriculture and river engineering. If river restoration is to have an ecological, as opposed to 'cosmetic' design basis then baseline models are required. However, this poses three questions; (a) what is the natural river-floodplain state, (b) how can it be defined and modelled and (c) can this state be recreated today? The first two questions can only be addressed by using palaeohydrological and palaeoecological data. A second and equally vital consideration is the stability/instability of any restored system to change in external forcing factors (e.g. climate) and in this context it may not be realistic to expect baseline models to provide equilibrium solutions but instead to define process-form domains. Over the last two decades evidence has accumulated that the natural state of lowland rivers in much of NW Europe was multi rather than single thread-braided, anastomosing or anabranching. Until recently our knowledge of floodplain palaeoecology was generally derived from pollen diagrams, which have source-area of problems and lack of taxonomic specificity. The precision and breadth of palaeoecological reconstruction (including richness and structure) has been greatly increased by the use of multiple palaeo-indicators including macrofossils, diatoms and beetles. The dynamics of small to medium sized, low-energy, predeforestation floodplains were dominated by disturbance (windthrow, beavers, etc.) and large woody debris. In order to compare the hydrogeomorphological basis of floodplain ecology, both temporally and spatially, a simple index of fluvial complexity is presented. Palaeoecological and geomorphological investigations have the potential to provide in-depth models of the natural range of channel conditions and sensitivity to external change that can be used to provide a scientific basis for floodplain restoration. There is also the possibility that floodplain-channel restoration may be a valuable tool in the mitigation of future geomorphological change forced by climatic instability.

Chapa-Vargas, L. and S. K. Robinson. 2007.
Nesting success of acadian flycatchers (Empidonax virescens) in floodplain forest corridors.
The Auk: a quarterly journal of ornithology. 124:1267-1280.
Reconnecting forest patches, including those of floodplain forest, often involves the creation of long, narrow corridors that have the potential to act as ecological traps for wildlife. We examined the effect of forest width and habitat composition of the landscapes immediately around nest patches on survival and parasitism of 359 Acadian Flycatcher (Empidonax virescens) nests in the Cache River Bioreserve in southern Illinois. Nests were distributed among 19 floodplain forest corridors along a small river system that is being restored and reconnected along its original floodplain. The corridors spanned a range of widths (80-3,170 m) and varied with the presence

or absence of natural water-related habitats (beaver ponds, backwater swamps, and creeks). Although nest success varied slightly between stages of the breeding cycle, confidence intervals overlapped, which suggests constant nest success throughout the breeding cycle. Nest survival was relatively high by regional standards but did not vary significantly with any of the landscape variables measured. Contrary to predictions, probabilities of brood parasitism decreased with increasing proportions of anthropogenic habitats surrounding nests. Probabilities of brood parasitism also decreased, but only slightly, as the breeding season progressed. Finally, Acadian Flycatcher nests were located significantly more often near natural (forest-water interface) edges than expected at random. Narrow corridors such as those along floodplain restoration projects do not necessarily create ecological traps for all forest species. Acadian Flycathcers, however, are one of the only forest-nesting Neotropical migrants that nest in narrow corridors and, therefore, may be less vulnerable to negative effects of fragmentation.

Dollar, T. 2002.
Leave it to beavers.
Wildlife Conservation. 105:28-35 | 28.
The author describes the role beavers play in maintaining the wetland ecosystem at San Pedro Riparian National Conservation Area in Arizona. Human activities like mining, grazing, and woodcutting in the late 19th century and urbanization and water pumping recently, led to severe degradation of this ecosystem. The San Pedro River over the years was severely diminished by human activities and the beavers that were a natural part of the ecosystem were wiped out by poaching. In 1988, in a series of land exchanges the 58,000 acre San Pedro Riparian National Conservation Area, encompassing a 40 mile stretch of the river, was established under the management of the U.S. Bureau of Land Management (BLM). Since March 1999, 10 beavers were trapped from several areas, fitted with radio-transmitters, and reintroduced to the San Pedro NCA where they immediately formed pairs and started their damming activities. Biologists hope that in the coming years around 20 beaver colonies will develop along the river. Wildlife biologist Mark Fredlake, who monitors the activities of the reintroduced beavers, observed that after a wildfire and devastating floods that damaged four of the five beaver dens, the beavers survived and got back to building dams. Beaver dams help restore the ecosystem and the largest of the dams, 75 feet wide and around 3 m high, had backed water for a quarter-mile upstream. Areas that had dried up over the years started to re-grow wetland vegetation. With protection, the habitat has improved and around 220 species of birds are reported to breed here and over 450 bird, 47 amphibian and reptile, and 100 butterfly species have been observed. However, urban sprawl and unchecked water pumping is draining the river and all efforts of the beavers will come to naught unless these activities are checked.

Harris, D. and S. E. Aldous. 1946.
Beaver management in the northern Black Hills of South Dakota.
Journal of Wildlife Management. 10:348-353.
History of beavers in the region and of early and present-day trapping. Once nearly exterminated, the animals have been restored by transplanting to prepared sites and by well-planned management. These operations are described. A live trap is illustrated and trapping for fur under State control is described.

Hood, G. A. and S. E. Bayley. 2003.

Fire and beaver in the boreal forest-grassland transition off western Canada - A case study from Elk Island National Park, Canada.
Lutra. 46:235-241.
Prescribed fire is used as a management tool in many areas throughout the world to restore vegetation communities, reduce fuel loading, and enhance wildlife habitats. However, the effect of prescribed fire on many wildlife species has not been well studied, especially on beavers (Castor canadensis). The purpose of our study was to examine whether prescribed fire influences beaver lodge occupancy in the aspen and mixed-wood habitats of Elk Island National Park, Alberta, Canada. In particular, we examined whether lodges in burned habitats experience lower occupancy levels than lodges in unburned habitats, whether the frequency of burns influences lodge abandonment, and whether the distance to suitable habitat potentially accessible from those lodges abandoned following a burn, influence beaver lodge occupancy. Since 1979, over 51% of Elk Island National Park (196 km2) has been burned with the goal of restoring prairie plant communities. We found that fire negatively affected beaver lodge occupancy, an effect compounded with frequent burns. Though prescribed fire is considered an important landscape restoration process, the frequency of prescribed burning should be mitigated to ensure that flooding by beavers can continue as a key process that maintains wetlands on the landscape.

Johnston, D. B., D. J. Cooper and N. T. Hobbs. 2007.
Elk browsing increases aboveground growth of water-stressed willows by modifying plant architecture.
Oecologia. 154:467-478 | 467-78.
In the northern elk wintering range of Yellowstone National Park, USA, wolf (Canis lupus) removal allowed elk (Cervus elaphus) to overbrowse riparian woody plants, leading to the exclusion of beaver (Castor canadensis) and a subsequent water table decline in many small stream valleys. Reduced elk browsing following wolf reintroduction may or may not facilitate willow (Salix sp.) recovery in these areas. To determine if the effect of elk browsing on willow interacts with that of beaver abandonment, we manipulated elk browsing and the water table in a factorial experiment. Under the condition of an ambient (low) water table, elk browsing increased shoot water potential ([psi]s), photosynthesis per unit leaf area (A), stomatal conductance per unit leaf area (gs), and aboveground current annual growth (CAG) by 50%. Elk browsing occurred entirely during dormancy and did not affect total plant leaf area (L). Improved water balance, photosynthetic rate, and annual aboveground productivity in browsed willows appeared to be due to morphological changes, such as increased shoot diameter and decreased branching, which typically increase plant hydraulic conductivity. An elevated water table increased [psi]s, A, gs, CAG, and L, and eliminated or lessened the positive effect of browsing on CAG for most species. Because low water tables create conditions whereby high willow productivity depends on the morphological effects of annual elk browsing, removing elk browsing in areas of water table decline is unlikely to result in vigorous willow stands. As large willow standing crops are required by beaver, a positive feedback between water-stressed willow and beaver absence may preclude the reestablishment of historical conditions. In areas with low water table, willow restoration may depend on actions to promote the re-establishment of beaver in addition to reducing elk browsing.

Kiesow, A. M. and C. Dieter. 2002.
Determining the feasibility of restoring river otters in South Dakota.

South Dakota Academy of Science. Proceedings. 81:279.
[unedited] Currently river otters occupy half their historic range in the United States and Canada. The status of the river otter in South Dakota is unknown; it is a state-threatened species. The purpose of this study was to determine the current status of river otters in South Dakota and to evaluate state river systems to ascertain the feasibility of restoring river otters in South Dakota. The sampled rivers were selected by buffering specific features, such as stream ranks 3-7, low gradient, and permanent water flow, using South Dakota GAP stream reach and watershed data. Study sites were selected along each river according to beaver activity, habitat quality (e.g. riparian areas), and accessibility. At each study site a riparian habitat transect was conducted recording floral and faunal species and a water sample was collected analyzing overall water quality. State employees and public conservation/management groups were contacted for further information on river otter sightings, habitat suitability, and restoration effort viewpoints. Rivers were rated (1 = poor to 5=excellent) based on stream characteristics, watershed features, water quality, logistical factors, and prey availability. The five highest rated river systems in South Dakota are the big Sioux R. (91), Little White R. (90), James R. (87), Bad R. (86), and North Fork whetstone R (86). For a successful river otter restoration in South Dakota, recommend releasing river otters in the five highest rated rivers in South Dakota.

MacCracken, J. G. 2000.
Wildlife response to salmon habitat enhancements on the Bear River, southwest Washington. Northwestern Naturalist. 81:82.
In 1997, large wood was added to 13 sites in the Bear River of southwest Washington and four kilometes of riparian red alder (Alnus rubra) forest were thinned and planted to conifer. Small mammal and amphibian abundance was similar (P=0.45) between thinned and control red alder stands from 1997-99. Beaver (Castor canadensis) activity increased and dam construction was often associated with an introduced large wood structure. edited by pcp.

MacCracken, J. G. and A. D. Lebovitz. 2005.
Selection of in-stream wood structures by beaver in the Bear River, southwest Washington. Northwestern Naturalist. 86:49-58.
[unedited] Many habitat restoration projects for Pacific salmon (Oncorhynchus spp.) have placed wood structures in streams. We observed beaver (Castor canadensis) consistently using three wood structures placed in the Bear River as foundations for dams, which provided pool habitat for juvenile salmon. Determining why beaver used some structures and not others could help to increase the efficacy of wood placement through use by beaver. We conducted an exploratory study using model selection procedures based on Akaike's information criteria to assess the hypothesis that there were characteristics of the wood structures and their immediate environment that influenced use by beaver. A literature review and field observations were used to develop seven logistic regression models and the parameters of those models were estimated with data from 55 in-stream wood structures. One model had overwhelming support (Akaike weight = 0.9801) as the best in the set of seven examined. Variables in that model described both in-stream characteristics (channel confinement; and distance to log jams, deep pools, and beaver bank dens) and riparian conditions (floodplain width and hillside slope). Structures used by beaver were in unconfined channels, farther from other logjams, closer to deep pools and bank dens, in wider floodplains, and with less steep hillsides. The logistic regression model is a

resource selection probability function that may be useful in designing wood placement projects if restoration ecologists and managers wish to enlist the services of beaver.

McKinstry, M. C. and S. H. Anderson. 1999.
Attitudes of private-and public-land managers in Wyoming, USA, toward beaver.
Environmental Management. 23:95-101.
Researchers sent a mail survey concerning management of beaver in Wyoming to 5265 private-land managers and 124 public land managers in 1993. Primary concerns about beaver damage included, in order of decreasing importance, blocked irrigation ditches; girdled timber; blocked culverts; and flooded pastures, roads, crops, and timber. Primary benefits that landowners believed resulted from beaver were in order of importance, elevated water tables, increased riparian vegetation, and increased stock-watering opportunities. Perceived benefits and detriments of beaver were similar for managers of public and private holdings. klf.

Messineo, J. 1998.
The first pond.
Farm Pond Harvest. 32:22-23.
The author emphasizes the importance of beavers and their ponds to farmers. Methods of successfully reintroducing beavers to a rural area are discussed. lgh.

Mitsch, W. J., J. W. Day and J. W. Day Jr. 2004.
Thinking big with whole-ecosystem studies and ecosystem restoration - a legacy of H.T. Odum.
Ecological Modelling. 178:133-155.
Whole-ecosystem studies are in situ ecological studies and experiments of such a spatial and temporal scale as to include most if not all processes of the ecosystem. Principles of self-organization and self-design are key to whole-ecological function and often do not occur as vibrantly or conclusively at smaller scale experiments. Ecological feedback caused by organisms (e.g., beavers, plants that manage hydrology, ecosystem engineers, top-down control), pulses caused by events such as fire and floods, and emergent ecosystem properties caused by human wastes, recycling, and hydrologic modification are difficult if not impossible to be properly studied in small-scale experiments. Large-scale whole-ecosystem studies were pioneered in the 1960s and 1970s by H.T. Odum and colleagues with large drop nets in Texas coastal bays, rain forests enclosures in Puerto Rico, created coastal ponds in North Carolina, and sewage application to cypress swamps in Florida. The study in Florida investigated effects of wastewater additions to wetland function in cypress domes but unexpected fire in the experimental area led to adaptive research and the study of fire in field research and models. More recently we have been engaged in whole-ecosystem experiments, partially inspired by the work of Odum, at created wetlands in northeastern Illinois to investigate effects of water turnover on ecosystem function and in Ohio to provide insight on the long-range large-scale effects of hydrology and macrophyte planting on ecosystem function. We have also carried out major ecosystem-scale studies in coastal Louisiana, investigating the value of these ecological systems in treating wastewater and restoring lost landscape in coastal Louisiana. These studies in the Midwest and Mississippi delta form the basis of determining design standards on creating and restoring wetlands in the Mississippi River Basin to reduce the Gulf of Mexico hypoxia and regain many lost ecosystem functions over a large part of North America. [copyright] 2004 Elsevier B.V. All rights reserved.

Pence, L. 1991.
Riparian restoration using beaver.
32-34.

Perry, C. 1945.
Beaver crisis in the Northeast.
American Forests. 51:72-73.
The "seamy side" of beaver restoration, including destruction of trees intended for reforestation, damage to trout streams, flooding of highways, and interference with city water supplies. Conservation officers quoted to the effect that there is little room for beavers in Massachusetts. Recent history in New York from a publication already noticed in WILDLIFE REVIEW (32, Nov. 1941, pp. 40-41). The statement is rather strong but the recommendations boil down to management. Conclusions: "Beavers may be 'friends of the forest,' but in the Northeast they certainly are not friends of the farmer, the railroad man, the highway engineer, or the lumberman; in many areas they are 'misplaced weeds.' The big problem is to keep them in locations where they belong. But it is doubtful if this can be accomplished short of immense expense, or without increased controlled trapping and transplanting of many areas remote from civilization, or through concentrated use of beavers on flood control and water conservation projects as is now done in some regions of the country."

Pollock, M. M., G. R. Pess and T. J. Beechie. 2004.
The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA.
North American Journal of Fisheries Management. 24:749-760.
The use of beaver Castor canadensis ponds by juvenile coho salmon Oncorhynchus kisutch and other fishes has been well established. However, the population-level effects on coho salmon resulting from the widespread removal of millions of beaver and their dams from Pacific Coast watersheds have not been examined. We assessed the current and historic distributions of beaver ponds and other coho salmon rearing habitat in the Stillaguamish River, a 1,771-km2 drainage basin in Washington and found that the greatest reduction in coho salmon smolt production capacity originated from the extensive loss of beaver ponds. We estimated the current summer smolt production potential (SPP) to be 965,000 smolts, compared with a historic summer SPP of 2.5 million smolts. Overall, current summer habitat capacity was reduced by 61% compared with historic levels, most of the reduction resulting from the loss of beaver ponds. Current summer SPP from beaver ponds and sloughs was reduced by 89% and 68%, respectively, compared with historic SPP. A more dramatic reduction in winter habitat capacity was found; the current winter SPP was estimated at 971,000 smolts, compared with a historic winter SPP of 7.1 million smolts. In terms of winter habitat capacity, we estimated a 94% reduction in beaver pond SPP a 68% loss in SPP of sloughs, a 9% loss in SPP of tributary habitat, and an overall SPP reduction of 86%. Most of the overall reduction resulted from the loss of beaver ponds. Our analysis suggests that summer habitat historically limited smolt production capacity, whereas both summer and winter habitats currently exert equal limits on production. Watershed-scale restoration activities designed to increase coho salmon production should emphasize the creation of ponds and other slow-water environments; increasing beaver populations may be a simple and effective means of creating slow-water habitat.

Pruss, M., R. Olding and C. Pruss. 1999.
Call it "Beaver River" again.
Arizona Wildlife Views. 42:19-21.
The authors discuss the successful restoration of the beaver population in the San Pedro River, Arizona. pcp.

Snodgrass, J. W. 1997.
Temporal and spatial dynamics of beaver-created patches as influenced by management practices in a south-eastern North American landscape.
Journal of Applied Ecology. 34:1043-1056.
Beavers create habitat diversity across catchment landscapes by impounding small streams. This increased habitat diversity leads to increased species richness of plants and animals in small streams. As managers work to balance conflicting management goals (e.g. protection of timber and human structures versus maintenance of biological diversity) the influence of beaver population management practices on habitat availability needs to be assessed. Two initial concerns are: (i) the effect of different levels of management on the availability of beaver created habitats; and (ii) whether relationships developed in one region apply to other regions. To address these questions, historical aerial photography was used to determine the extent and rate of impoundment of streams by beavers (<i>Castor canadensis</i>) over the 77000 ha Savanna River Site on the Upper Coastal Plain of South Carolina during a 40-yr period of beaver population recovery. Between 1950 and 1983, beaver populations were protected from trapping and hunting. From 1983 to the present, beaver numbers were reduced by fatal trapping, to protect roads, railroads and timber. Trapped beavers were assigned to specific colonies associated with beaver-created patches in the landscape, and growth rates and size after management of individual patches receiving different levels of management were compared. Results from this study were also compared with previous studies conducted in Minnesota. Growth rate, patch size following management, and the composition of habitat types within patches were not related to management activity, suggesting that the levels of management used in this study did not influence the temporal dynamics of beaver-created patches. The extent and rate of beaver impoundment at the Savanna River Site was less than that reported from central North American landscapes over comparable periods. These results have the following implications for management: (i) management activities should be monitored on a regional basis; (ii) conflicting beaver population management goals should be addressed, evaluated and balanced; and (iii) beavers do not present a threat to flowing-water species in south-eastern North America and need not be controlled for this reason.

Voelker, B. W. and J. L. Dooley. 2006.
Impact on woody plants by the North American beaver (Castor Canadensis) at the wilds, Muskingum County, Ohio.
The Ohio Journal of Science. 105:A9-A10.
[unedited] The Wilds, a 4,050 hectare center for wildlife conservation, of southeastern Ohio has a history of intense surface-mining and provides an important opportunity for advancing restoration ecology. There is concern that the herbivory pressure of beaver (Castor canadensis) may negatively affect the restoration processes in the northern section of the property restored in 1973-1975. The canopy-opening foraging and selective feeding of beavers could influence the

structure and diversity of woody plant communities. This study will assess the impact of beaver on an ecosystem recovering from surface-mining where the short-term and, more importantly, the long term effects of such beaver foraging on woody plants and therefore ecosystem recovery need to be quantitatively assessed. To study the influence of beaver on shoreline woody plants, one active and two recently abandoned beaver dam sites were chosen. Transects were established at all three sites and the following data recorded: woody plant diameter, species identity and cutting history by beaver. Analysis of these data will allow determination if browse selection affects the woody plant community at these sites and to assess the degree to which forest succession and recovery may be altered by beaver herbivory in terms of species richness, diversity and evenness.

Wilson, K. A. 1955.
The beaver in North Carolina.
Wildlife in North Carolina. 19:6-8.
History and present status. Favorable and unfavorable effects of beaver are discussed. There are about 5,000 beavers in N. C. now, most of them in a 5-county area around the restoration site, Sandhills Wildlife Management Area. Trapping season was opened for first time in recent years in spring of 1955.

Wolf, E. C., D. J. Cooper and N. T. Hobbs. 2007.
Hydrologic regime and herbivory stabilize an alternative state in Yellowstone National Park.
Ecological Applications. 17:1572-1587 | 1572-87.
The article focuses in determining the relative influence of hydrologic regimes, as controlled by climate variation, beaver damming, and landscape changes, on the process of Yellowstone's northern range. The study was made with four streams on the northern range of Yellowstone National Park, USA. The four streams were selected because they have relatively large willow populations, have a riparian zone where groundwater is supported by streamflows, and lack significant hillslope groundwater inflows. Willow establishment data were compared to 20th century streamflow and precipitation data in detecting climatic influences on the timing of establishment. The reduced frequency of willow establishment during the 20th century is likely both a direct and indirect effect of elk browsing.

<u>Trapping effects</u>

Bhat, M. G. 1992.
Controlling Wildlife Damage By Diffusing Beaver Population: A Bioeconomic Application of The Distributed Parameter Control Model.
Dissertation Abstracts International. Section A: Humanities and Social Sciences. 53:898-126.
The beaver population in the Southeastern United States has caused severe damage to valuable timber land through dam-building and flooding of bottom-land forest. The low beaver pelt price in the Southeast has failed to stimulate adequate trapping pressure, resulting in increased beaver damage on private timber lands. Since the beaver population is mobile, extermination of beavers from affected parcels results in migration of beavers from neighboring less controlled parcels to controlled parcels. This backward migration of beavers from uncontrolled habitat to controlled habitat imposes a negative diffusion externality on the owners of controlled parcels because they incur the cost of trapping immigrating beavers. This externality is likely to provide not enough

incentive for control of beaver population on the part of individual land owners, causing a wedge between social and private needs for controlling beaver population. This study attempts to develop a bioeconomic model that incorporates dispersive population dynamics of beavers into the design of a cost-minimizing trapping strategy. The model simulates the area-wide damage control strategy in a situation where all the land owners in a given habitat share common interest of controlling beaver nuisance, and collectively agree to place the control decision in the hands of a public agency. The public manager attempts to minimize the present value combined costs of beaver damage and trapping over a finite period of time subject to spatiotemporal dynamics of beaver population. The time and spatial dynamics of beaver population is summarized by the parabolic diffusive Volterra-Lotka partial differential equation. The cost-minimizing trapping strategy requires that the marginal damage savings from the beavers trapped at each location equal the marginal costs of trapping. The optimality system for this problem that characterizes the optimal trapping rates is solved numerically. Finally, the empirical simulation of the model generated discrete values for the optimal beaver densities and trapping rates. The sensitivity analysis indicates that increase in the damage potential of beavers could substantially increase the discounted cost, whereas the increase in beaver trapping cost adds marginally to the total cost, conserving more beavers.

Boyce, M. S. 1974.
Beaver population ecology in interior Alaska.
161:University of Alaska.

University of Alaska Thesis.Two populations of beaver were studied and correlated to trapping intensity. Descripton of the use of the pelvis in sex determination.

Boyce, M. S. 1981.
Beaver life-history responses to exploitation.
Journal of Applied Ecology. 18:749-753.
Human exploitation of beavers decreases the survivorship of adults, but by freeing high quality colony sites, results in enhanced survivorship for dispersing prereproductives. Females breeding earlier in life in an exploited population attain smaller size at maturity and consequently suffer higher mortality than individuals breeding Later at a larger body size. These trade-offs between fecundity, growth and survivorship are as predicted by recent theory on the evolution of life-histories. (Author)

Henry, D. B. and T. A. Bookhout. 1969.
Productivity of beavers in northeastern Ohio.
Journal of Wildlife Management. 33:927-932.
Productivity of beavers (Castor canadensis) from northeastern Ohio was calculated from analysis of 219 specimens (114 males, 105 females) collected in the 1966 and 1967 trapping seasons (Feb. 1-15). Beavers were aged by characteristics of eruption, closure of basal openings, and cementum layering of molar teeth. Seventy-four percent of breedingage females (1.5 years or older) had ovulated, but only 40 percent of 1.5-2-year-olds had ovulated. The mean ovulation rate for ovulating females was 4.3, and mean placental scar count was 3.8. Signs of implantation were present in 62 percent of breeding-age females. Mean ovulation rate, conception rate, and placental scar count increased to age 5.5-6 years. Estimated prenatal mortality was 11-16

percent. First-year trapping and natural mortality was calculated to be 41.6 percent. Estimated rate of annual population increase, including prenatal and juvenile mortality, was 49 percent. On this basis, a harvest rate of 32 percent would maintain a stable beaver population.

Kafcas, E. N. 1987.
Census and exploitation of a discrete beaver population in Michigan.
1987:89. Central Michigan University.

Purpose was to develop a census technique, while evaluating beaver exploitation rates under 1979 and 1980 trapping regulations. The census technique related year-to-year changes in colony population size with numbers of colonies present, using the food cache method. Data concerning reproduction, population dynamics,. age, weight and movements, and habitat condition were collected to assess effects of trapping regulations.

McTaggart, S. T. and T. A. Nelson. 2003.
Composition and demographics of beaver (Castor canadensis) colonies in central Illinois.
American Midland Naturalist. 150:139-150.
Beavers (Castor canadensis) exhibit wide variations in colony composition and demographics over their broad geographic range, so regional population studies are important for sound management of this species. The objectives of this study were to investigate the: (1) size and sex-age composition of beaver colonies in Illinois, (2) reproductive potential of female beavers in these colonies and (3) efficacy of night-vision surveys versus removal trapping for estimating colony size. We harvested and aged 239 beavers (128 males: 111 females) during the 1999-2000 and 2000-2001 trapping seasons. The average colony contained 5.6 beavers. Family groups consisting of a breeding pair and at least 1 offspring composed 86% of these colonies; the other 14% consisted of only a breeding pair. Samples of beavers harvested by commercial trappers were skewed towards yearlings and 2-y olds relative to samples taken from trapped-out colonies. Fetal rates were 3.0, 3.4 and 4.2/female for yearlings, 2-y olds and older adults, respectively. In utero loss was estimated as 13%. Our estimates suggest that over 50% of kits die during the first 6 mo of life. We found no evidence that the presence of older offspring in a colony allowed parents to raise more kits. Night-vision surveys conducted 10 m downwind from the den for 2.5 h after sunset underestimated the size of colonies, accounting for only 55% of the beavers present.

Parsons, G. R. 1975.
Effect of a 4-year closure of the trapping season for beaver in Eastern Warren County, New York.
New York Fish and Game Journal. 22:57-61.

Parsons, G. and M. Brown. 1978.
Effect of a four-year closure of trapping season for beaver in Fulton County.
New York Fish and Game Journal. 25:23-30.
Trapping for beaver in Fulton County was prohibited from 1969 to 1972, and the effects of the closure on the beaver population were evaluated. A substantial increase in beaver abundance insued, as evidenced by a calculated gain in the number of active colonies from 45 to 184. Beaver damage coplains also increased, plugging of road culverts being the principal type, but

unil the number of colonies exceeded 150 the cost of servicing complaints was considered reasonable. It was concluded that an occupancy of 30 to 40 per cent of the potential colony sites would be desirable and that trapping may be permitted under regulations designed to maintain the beaver population at that level.

Parsons, G. R. and M. K. Brown. 1981.
Season length as a method of achieving population objectives for beaver (Castor canadensis).
Proceedings of the Worldwide Furbearer Conference. 1392-1403.

Payne, N. F. 1989.
Population dynamics and harvest response of beaver.
Proceedings of the Fourth Eastern Wildlife Damage Control Conference. 127:127-132.
The author discusses beaver population control and various aspects of beaver life history. Habitat use, territoriality, colony size, dispersal, reproduction, mortality, and population response to harvesting are investigated in this paper.

Zeckmeister, M. T. and N. F. Payne. 1998.
Effects of trapping on colony density, structure, and reproduction of a beaver population unexploited for 19 years.
Wisconsin Academy of Sciences, Arts and Letters. Transactions. 86:281-291.
The authors studied the influence of trapping on colony density, structure, and reproduction of a beaver population that had not been trapped in 19 years. After 19 years of being closed to trapping, the beaver colony density in the Sandhill Wildlife Area of Wisconsin was 1.30 colonies/km2 compared to an adjacent trapped area which had a density of 0.42 colonies/km2. A winter harvest of 3.9 beavers/colony in 1981 resulted in a 21% decline in active colonies in 1982. The harvest of 3.2 beavers/colony in 1982 resulted in a 53% decline in 1983. slj.

Urban and road crossing impacts

Anonymous. 2003.
Beaver problems growing.
Coexisting with wildlife. 2003:
This article released in June 2000 deals with the increasing number of beaver problems in the state of Colorado (USA). In 1996, the voters of Colorado passed Amendment 14 that bans the use of leg-hold and kill traps in order to control beaver populations. Due to this most of the residents do nothing to control the damage even if it is not agriculture related. The agricultural exemption of the Amendment allows farmers to trap beavers one 30-day period a year. The most problematic animals are the lone male beavers living along the stream banks because they are difficult to trap. The non-lethal methods to deal with beavers are to wrap individual trees with fencing, use electric fencing around culverts, and use special pipes and grates for dams. Another non-lethal method is to apply a mixture of mason sand and latex paint on the tree bark. The lethal options are live trapping and shooting. Licensed trappers do live trapping. But this is not a permanent solution considering the ever-increasing number of beavers and related problems.

Anonymous. 1998.
Guidelines for Controlling Beavers and Preventing Roadway Damage.

Road Management & Engineering Journal. 4:

Curtis, P. D. and P. G. Jensen. 2004.
Habitat features affecting beaver occupancy along roadsides in New York State.
Journal of Wildlife Management. 68:278-287 | 278-288.
Characterizing habitat features that influence beaver (Castor canadensis) occupancy along roadsides may have important implications for managing damage to roads Caused by beaver activity. We initiated this study to develop proactive and long-term approaches to deal with nuisance beaver along roadsides. From June to October 1997 and 1998, we sampled 316 roadside sites in New York state, USA-216 sites where beaver occupied the roadside area and 100 unoccupied sites. We used stepwise logistic regression to identify habitat variables associated with beaver occupancy along roadsides. We evaluated regression models through measures of sensitivity and specificity. The logistic function retained the percentage of roadside area devoid of woody vegetation, stream gradient, the interaction between these 2 variables, and stream width in the final model. Precluding beaver occupancy along highways would necessarily involve large-scale removal of woody vegetation that would be impractical in all but the most intensive management scenarios. However, beaver habitat assessment adjacent to roads max, be a useful tool for designing new highways, prioritizing culvert replacements, and developing proactive plans for beaver damage management.

D'Eon, R. G. 1995.
Beaver handbook: A guide to understanding and coping with beaver activity.
Northeast Science & Technology, Ontario Ministry of Natural Resources.

Beavers are an important part of North American ecosystems, but can also cause problems such as road washouts and flooded timberland. This handbook is intended to help resource managers and field staff in northern Ontario address problems related to beaver activity. The information in the handbook was gathered from a survey of people with experience and knowledge of beaver problems. It includes a review of beaver biology and behavior, beaver management practices in Ontario, and beaver control measures that have been found effective in certain situations. These measures include various types of screens or grills for preventing beavers from blocking culverts and road crossings, beaver fences, and beaver pond levellers.

Destefano, S. and R. Deblinger. 2005.
Wildlife as valuable natural resources vs. intolerable pests: a suburban wildlife management model.
Urban Ecosystems. 8:179-190.
Management of wildlife in suburban environments involves a complex set of interactions between both human and wildlife populations. Managers need additional tools, such as models, that can help them assess the status of wildlife populations, devise and apply management programs, and convey this information to other professionals and the public. We present a model that conceptualizes how some wildlife populations can fluctuate between extremely low (rare, threatened, or endangered status) and extremely high (overabundant) numbers over time. Changes in wildlife abundance can induce changes in human perceptions, which continually redefine species as a valuable resource to be protected versus a pest to be controlled. Management programs thatincorporate a number of approaches and promote more stable

populations of wildlife avoid the problems of the resource versus pest transformation, are less costly to society, and encourage more positive and less negative interactions between humans and wildlife. We presenta case example of the beaver Castor canadensis in Massachusetts to illustrate how this model functions and can be applied. (Author)

DeStefano, S., K. K. G. Koenen, C. M. Henner and J. Strules. 2006.
Transition to independence by subadult beavers (*Castor canadensis*) in an unexploited, exponentially growing population.
Journal of Zoology. 269:434-441.
We conducted a 4-year study of beavers Castor canadensis to compare the movements, survival and habitat of adults established in existing colonies to juveniles dispersing to new sites in a region with high beaver densities along a suburban-rural gradient. Estimates of annual survival were high for adult and juvenile beavers. Of nine known mortalities, seven (78%) were juveniles. Mortalities occurred during spring-summer, and none during fall-winter. There was a trend toward higher-to-lower survival along the suburban-rural gradient, respectively. Human-induced mortality (e.g. trapping and shooting) was higher in rural areas, whereas nonhuman-induced mortality (e.g. disease, accidents) was higher in suburban areas. Fifteen (14 subadults and one adult) beavers moved from natal colonies to other areas. The average dispersal distance for subadults was 4.5 km (SE=1.0) along streams or rivers, or 3.5 km (SE=0.7) straight-line point-to-point. Most dispersal movements were made in spring (April-June). In two cases, individual subadults made return movements from their dispersal sites back to their natal colonies. Dispersal sites tended to be in smaller, shallower wetlands or streams and in areas with higher overstorey canopy closure compared with natal colonies. Woody vegetation usually preferred by beavers for food tended to be less common at dispersal sites than at natal colonies. In regions with high densities of beaver, dispersing juveniles are likely to attempt to colonize lower quality sites. High densities of beavers also lead to more human-beaver conflicts and, in Massachusetts, the pest control management options in place during the past decade have been ineffectual at controlling population levels. Alternately, in regions with no beavers or very low densities and where reintroductions are being attempted, the landscape matrix surrounding release sites should include suitable sites for dispersing young to establish colonies.

Dickins, J. H., D. W. Clark, S. C. White and G. A. Heidt. 1999.
Survey of medium and large mammals in an urban park (Murray Park), Little Rock, Pulaski County, Arkansas.
J. Arkansas Acad. Sci. 53:41-44.
Because of increased environmental awareness by city planning commissions, there are more urban parks and greenbelt areas. These areas often result in increased human and wildlife contacts, thus resulting in the need for management plans regarding urban wildlife. From September 1998 to March 1999, we conducted mammal surveys of the urban greenspace Murray Park, Little Rock, Pulaski County, Arkansas. Surveys were conducted using five methods: direct observations; spot lighting; live trapping; animal sign; and scent posts. Species recorded included, opossum (Didelphis virginiana), nine-banded armadillo (Dasypus novemcinctus), fox squirrel (Sciurus niger), gray squirrel (Sciurus carolinensis), beaver (Castor canadensis), woodchuck (Marmota monax), muskrat (Ondatra zibethicus), eastern cottontail rabbit (Sylvilagus floridanus), swamp rabbit (Sylvilagus aquaticus), coyote (Canis latrans), red fox (Vulpes vulpes), raccoon (Procyon lotor), mink (Mustela vison), river otter (Lontra canadensis),

bobcat (Lynx rufus), skunk sp., white-tailed deer (Odocoileus virginianus) and domestic dog (Canis familiaris) and cat (Felis sylvestris). These species represent 19 of the 23 mammals expected in surrounding natural areas. Management plans for urban wildlife need to include all mammals that potentially occur in the area.

Dollar, T. 2002.
Leave it to beavers.
Wildlife Conservation. 105:28-35 | 28.
The author describes the role beavers play in maintaining the wetland ecosystem at San Pedro Riparian National Conservation Area in Arizona. Human activities like mining, grazing, and woodcutting in the late 19th century and urbanization and water pumping recently, led to severe degradation of this ecosystem. The San Pedro River over the years was severely diminished by human activities and the beavers that were a natural part of the ecosystem were wiped out by poaching. In 1988, in a series of land exchanges the 58,000 acre San Pedro Riparian National Conservation Area, encompassing a 40 mile stretch of the river, was established under the management of the U.S. Bureau of Land Management (BLM). Since March 1999, 10 beavers were trapped from several areas, fitted with radio-transmitters, and reintroduced to the San Pedro NCA where they immediately formed pairs and started their damming activities. Biologists hope that in the coming years around 20 beaver colonies will develop along the river. Wildlife biologist Mark Fredlake, who monitors the activities of the reintroduced beavers, observed that after a wildfire and devastating floods that damaged four of the five beaver dens, the beavers survived and got back to building dams. Beaver dams help restore the ecosystem and the largest of the dams, 75 feet wide and around 3 m high, had backed water for a quarter-mile upstream. Areas that had dried up over the years started to re-grow wetland vegetation. With protection, the habitat has improved and around 220 species of birds are reported to breed here and over 450 bird, 47 amphibian and reptile, and 100 butterfly species have been observed. However, urban sprawl and unchecked water pumping is draining the river and all efforts of the beavers will come to naught unless these activities are checked.

Hadidian, J. 2003.
Managing conflicts with beaver in the United States: an animal welfare perspective.
Lutra. 46:217-222.
As had happened earlier in Europe, the American beaver (Castor canadensis) was almost completely extirpated from its historic range because of human exploitation. Anywhere from 50 to 400 million beaver may have occurred throughout North America prior to the arrival of Europeans. Today, the population in the United States has recovered from unknown historic lows to a point where conflicts with humans have notably increased. The standard approach to resolving human-beaver conflicts has been to kill beaver and destroy their structures. From both an environmental as well as animal welfare perspective this approach is regarded as short-sighted. This paper addresses the issue of humane and environmentally responsible beaver conflict management, and identifies alternatives that control the problems beaver cause without necessitating their removal. It also addresses the benefits created by the presence of beaver in even highly urbanized ecosystems and details the strategy of one animal protection organization, the Humane Society of the United States, to educate the public about the beneficial role these animals can play.

Hedeen, S. E. 1985.
Return of the beaver, Castor canadensis, to the Cincinnati region.
The Ohio Journal of Science. 85:202-203.

Hoene, J. V. 1946.
North Woods beaver trouble.
American Forests. 52:538-539.
Thousands of dollars' worth of timber is being destroyed in Minnesota by beavers flooding woodland by blocking drainage ditches. Losses particularly heavy in the International Falls area are greater than those due to fire. Not only are standing trees killed but new growth is prevented. There is also considerable damage to roads. Trapping should be directed toward restricting beavers to hilly parts of the State where their presence is less harmful.

Jakes, A. F., J. W. Snodgrass and J. Burger. 2007.
Castor canadensis (Beaver) Impoundment Associated with Geomorphology of Southeastern Streams.
Southeastern Naturalist. 6:271-282.
We used a geographic information system (GIS) and logistic regression to investigate relationships between geomorphology and Castor canadensis (North American beaver) impoundment of lower-order, blackwater streams of a southeastern landscape. Using GIS, we divided streams into 632 500-m reaches and measured a set of geomorphic variables for each reach. Beavers were most likely to impound stream reaches crossed by roads with a gradient of ? 0.6 to 1.2% and watershed sizes of ? 2500 ha; reaches with watershed sizes < ? 500 ha or > 5000 ha were almost completely avoided. Gradient and road crossings contributed little to discrimination among impounded and unimpounded reaches, suggesting these variables had relatively small influences on beaver impoundment when compared to stream size. Our results indicate that GIS and geomorphic variables can be used to model the impoundment of streams over larger areas (e.g., the proportion of third-order watersheds impounded), but are less accurate at predicting the impoundment of individual reaches. However, the temporal dynamics of impoundment creation and abandonment will need to be incorporated into region-specific models before they can be used in ecosystem integrity assessment. (Author)

Jensen, P. G., P. D. Curtis, M. E. Lehnert and D. L. Hamelin. 2001.
Habitat and structural factors influencing beaver interference with highway culverts.
Wildlife Society Bulletin. 29:654-664 | 654.
The plugging of highway culverts by beavers (Castor canadensis) creates roadside impoundments that damage and sometimes flood the roadbed. Continually mitigating these problem sites requires considerable time, money, and resources from town, country, and state highway departments. The authors initiated this study to develop proactive and long-term approaches to deal with nuisance beavers along roadsides. Their specific objective was to compare culvert and habitat features at plugged and nonplugged culverts. From June to October 1997 and 1998, they sampled 216 roadside sites in New York state: 113 sites where beavers plugged the highway culvert and 103 sites where beavers did not plug the culvert but instead constructed an upstream or downstream dam. They used stepwise logistic regression (SLR) to identify key variables associated with plugged culverts. They evaluated classification rates of regression models with measures of sensitivity and specificity. For the combined data set, the

logistic function retained culvert inlet opening area (m~2~) and stream gradient in the final model. Based on the two variables, the model correctly classified 79% of the sites. The results of the study indicated that installing oversized culverts would have the greatest influence on discouraging beaver plugging activity. Prorated over the service life of culverts, the installation of oversized culverts by highway departments may be more cost-effective than trapping, debris removal, or other short-term options to manage beaver damage to roads.

Jonker, S. A., R. M. Muth, J. F. Organ, R. R. Zwick and W. F. Siemer. 2006.
Experiences with beaver damage and attitudes of Massachusetts residents toward beaver.
Wildlife Society Bulletin. 34:1009-1021.
As stakeholder attitudes, values, and management preferences become increasingly diverse, managing human-wildlife conflicts will become more difficult. This challenge is especially evident in Massachusetts, USA, where furbearer management has been constrained by passage of a ballot initiative that outlawed use of foothold and body-gripping traps except in specific instances involving threats to human health or safety. Without regulated trapping, beaver (Castor canadensis) populations and damage attributed to them have increased. To develop an understanding of public attitudes regarding beaver-related management issues, we surveyed a random sample of Massachusetts residents in the spring of 2002 within 3 geographic regions where beaver are prevalent, as well as all individuals who submitted a beaver-related complaint to the Massachusetts Division of Fisheries and Wildlife in 1999 and 2000. We found that respondents held generally positive attitudes toward beaver. Respondents who experienced beaver-related problems tended to have less favorable or negative attitudes toward beaver than people who did not experience beaver damage. Attitudes toward beaver became increasingly negative as the severity of damage experienced by people increased. We believe continued public support for wildlife conservation will require implementation of strategies that are responsive to changing attitudes of an urban population and within social-acceptance and biological carrying capacities.

Laramie, H. A. J. 1963.
A device for control of problem beavers.
Journal of Wildlife Management. 27:471-476.
Beaver (Castor canadensis) dam-induced flooding has been controlled by use of beaver pipes in New Hampshire. These pipes, of fiber or wood and with multiple small openings along the length of the bottom portion, are placed through the dam and into the beaver pond. Height of outlet and length of pipe are factors in producing the desired water level. Installation of wire-mesh guards across the mouths of culverts tends to discourage rebuilding in culverts after the existing dam has been removed. New Hampshire now has 46 beaver dams with pipes installed and working well. All installations must be checked monthly and maintained as required. Beaver pipes are most useful on watersheds of less than 10 square miles. If culverts are involved, the maximum usable watershed is reduced to 4 square miles.

Loker, C. A., D. J. Decker and S. J. Schwager. 1999.
Social acceptability of wildlife management actions in suburban areas: 3 cases from New York.
Wildlife Society Bulletin. 27:152-159 | 152.
Despite notable successes, wildlife damage management in suburban situations is widely perceived as difficult because of the vocal resistance of some suburban residents to many

mitigation measures. We examined suburban residents' experiences with, concerns about, and acceptance of management actions for white-tailed deer (Odocoileus virginianus), beaver (Castor canadensis), or Canada geese (Branta canadensis) in three areas of New York state. We considered four types of interventions which represented degrees of invasiveness to the animals of concern: human behavior modification, nonlethal-noninvasive, nonlethal-invasive, and lethal. Results demonstrated that residents' concerns about wildlife were elevated by increasingly severe problem experiences. In addition, residents' acceptance of invasive and lethal methods to resolve wildlife problems in suburban areas was higher than many wildlife managers might expect. Contrary to our predictions, acceptance of invasive and lethal methods was more strongly related to concerns about nuisance and economic damage issues than to concerns about health and safety issues. Our results provide useful information to wildlife professionals for management planning and communication regarding problem-causing wildlife in suburban areas.

Maestrelli, J. R. 1990.
Urban animal damage control in California.
Proc. Vertebr. Pest Conf.
Proc. Vertebr. Pest Conf. No. 14. 156-159. University of California.

McKinstry, M. C. and S. H. Anderson. 1999.
Attitudes of private-and public-land managers in Wyoming, USA, toward beaver.
Environmental Management. 23:95-101.
Researchers sent a mail survey concerning management of beaver in Wyoming to 5265 private-land managers and 124 public land managers in 1993. Primary concerns about beaver damage included, in order of decreasing importance, blocked irrigation ditches; girdled timber; blocked culverts; and flooded pastures, roads, crops, and timber. Primary benefits that landowners believed resulted from beaver were in order of importance, elevated water tables, increased riparian vegetation, and increased stock-watering opportunities. Perceived benefits and detriments of beaver were similar for managers of public and private holdings. klf.

Organ, J. F. and M. R. Ellingwood. 2000.
Wildlife stakeholder acceptance capacity for black bears, beavers, and other beasts in the east.
Human Dimensions of Wildlife. 5:63-75.
The formal concept of wildlife stakeholder acceptance capacity (WSAC) in wildlife management is less than a generation old. The genesis of wildlife management in North America occurred during a time when populations of many wildlife species were low, their habitats were altered and degraded, and the human population was rapidly urbanizing. The focus of wildlife management was to restore wildlife populations and habitats. Once restored, wildlife managers strove to maintain populations at levels within biological carrying capacities (BCC) and provide benefits to a relatively narrow range of stakeholders. In recent years, cultural changes associated with a predominantly suburban society have led to conflicts with traditional wildlife management approaches and broadened the stakeholder base. Wildlife managers have had to consider the interests of a wider stakeholder base that supports a diversity of often conflicting expectations, while relying on traditional funding sources. For certain species, management for WSAC has taken priority over management for BCC. This scenario is particularly focused in the northeast United States where human population densities are some of the highest in the nation. The authors explore the current state of knowledge of WSAC for certain species in the east, and

review the tools being used for monitoring and assessment. They discuss adequacy of these approaches and offer suggestions for incorporating WSAC into wildlife management planning and operations. They consider the implications of WSAC to the future of wildlife management in North America.

Parsons, G. and M. Brown. 1978.
Effect of a four-year closure of trapping season for beaver in Fulton County.
New York Fish and Game Journal. 25:23-30.
Trapping for beaver in Fulton County was prohibited from 1969 to 1972, and the effects of the closure on the beaver population were evaluated. A substantial increase in beaver abundance insued, as evidenced by a calculated gain in the number of active colonies from 45 to 184. Beaver damage coplains also increased, plugging of road culverts being the principal type, but unil the number of colonies exceeded 150 the cost of servicing complaints was considered reasonable. It was concluded that an occupancy of 30 to 40 per cent of the potential colony sites would be desirable and that trapping may be permitted under regulations designed to maintain the beaver population at that level.

Purdy, K. G., D. J. Decker and R. A. Malecki. 1987.
Highway superintendents' tolerance of beaver damage in New York.
Transactions of the Northeast Section of the Wildlife Society. 44:72-76.

Roblee, K. J. 1984.
Use of corrugated plastic drainage tubing for controlling water levels at nuisance beaver sites.
New York Fish and Game Journal. 31:63-80 | 62-80.

Roblee, K. J. 1987.
The use of the T-culvert guard to protect road culverts from plugging damage by beavers.
3:25-33.

Wittmann, K., J. J. Vaske, M. J. Manfredo and H. C. Zinn. 1998.
Standards for lethal response to problem urban wildlife.
Human Dimensions of Wildlife. 3:29-48.
Managers face limited options when dealing with problems created by urban wildlife. Destroying an animal that is perceived to be a nuisance is sometimes acceptable; at other times destroying the animal may be controversial. This paper uses the structural norm approach to develop standards for an agency's use of lethal response to problem urban wildlife. The paper describes three structural characteristics of public wildlife management norms (range of acceptable situations, norm intensity, and norm agreement) and shows how these standards may be affected by different situational contexts (impact severity) and different animal species. Three wildlife species (beavers, coyotes, and mountain lions) are examined across a continuum of situation contexts ranging from seeing wildlife in a residential area to an animal killing a person. For all three species, acceptability of destroying the animal increased as the impact severity of the human-wildlife interaction increased. For identical situations, however, acceptability of destroying an animal varied by species. Overall, the normative approach can effectively clarify the positions of constituents on wildlife management decisions for specific contexts and animal

species. Such information can decrease the risk of public controversy generated by general broad-based wildlife management policies.

Wetland function and restoration

Albert, S. 1999.
The beaver and the flycatcher.
Endangered Species Bulletin. 24:16-17.
The author discusses the status of the North American beaver and the southwestern willow flycatcher. In a semi-arid region the beaver provides many benefits to other species. The flow of water is slowed down by the construction of beaver dam and this, in turn, allows the sediment to drop out and the water to percolate into the soil thus maintaining a high water table that will contribute to greater abundance and diversity of riparian vegetation and wildlife. In the 18th and 19th centuries the North American beaver populations started declining and the southwestern willow flycatcher species became endangered. With the help of beavers the Zuni Reservation in the semi-arid high desert of the Colorado Plateau began restoring riparian and wetland habitats. Small numbers of beavers were moved to streams containing abundant food. As the stream channel was incised it did not hold water year round. Existence of beavers in the area began to make a difference. The beaver dams helped slow down the flow of water and sediment to drop out. The water table began spreading over a wider area and thicker, lush, riparian vegetation began to be established. With better vegetation and habitat wildlife also improved in the riparian areas. With the open water pairs of flycatchers started establishing territories near the active beaver dams. The farmers who had initially complained about the beaver program benefited from the beaver dam water during the 1996 drought period.

Dollar, T. 2002.
Leave it to beavers.
Wildlife Conservation. 105:28-35 | 28.
The author describes the role beavers play in maintaining the wetland ecosystem at San Pedro Riparian National Conservation Area in Arizona. Human activities like mining, grazing, and woodcutting in the late 19th century and urbanization and water pumping recently, led to severe degradation of this ecosystem. The San Pedro River over the years was severely diminished by human activities and the beavers that were a natural part of the ecosystem were wiped out by poaching. In 1988, in a series of land exchanges the 58,000 acre San Pedro Riparian National Conservation Area, encompassing a 40 mile stretch of the river, was established under the management of the U.S. Bureau of Land Management (BLM). Since March 1999, 10 beavers were trapped from several areas, fitted with radio-transmitters, and reintroduced to the San Pedro NCA where they immediately formed pairs and started their damming activities. Biologists hope that in the coming years around 20 beaver colonies will develop along the river. Wildlife biologist Mark Fredlake, who monitors the activities of the reintroduced beavers, observed that after a wildfire and devastating floods that damaged four of the five beaver dens, the beavers survived and got back to building dams. Beaver dams help restore the ecosystem and the largest of the dams, 75 feet wide and around 3 m high, had backed water for a quarter-mile upstream. Areas that had dried up over the years started to re-grow wetland vegetation. With protection, the habitat has improved and around 220 species of birds are reported to breed here and over 450 bird, 47 amphibian and reptile, and 100 butterfly species have been observed. However, urban

sprawl and unchecked water pumping is draining the river and all efforts of the beavers will come to naught unless these activities are checked.

Hood, G. A. and S. E. Bayley. 2003.
Fire and beaver in the boreal forest-grassland transition off western Canada - A case study from Elk Island National Park, Canada.
Lutra. 46:235-241.
Prescribed fire is used as a management tool in many areas throughout the world to restore vegetation communities, reduce fuel loading, and enhance wildlife habitats. However, the effect of prescribed fire on many wildlife species has not been well studied, especially on beavers (Castor canadensis). The purpose of our study was to examine whether prescribed fire influences beaver lodge occupancy in the aspen and mixed-wood habitats of Elk Island National Park, Alberta, Canada. In particular, we examined whether lodges in burned habitats experience lower occupancy levels than lodges in unburned habitats, whether the frequency of burns influences lodge abandonment, and whether the distance to suitable habitat potentially accessible from those lodges abandoned following a burn, influence beaver lodge occupancy. Since 1979, over 51% of Elk Island National Park (196 km2) has been burned with the goal of restoring prairie plant communities. We found that fire negatively affected beaver lodge occupancy, an effect compounded with frequent burns. Though prescribed fire is considered an important landscape restoration process, the frequency of prescribed burning should be mitigated to ensure that flooding by beavers can continue as a key process that maintains wetlands on the landscape.

Hood, G. A., S. E. Bayley and W. Olson. 2007.
Effects of prescribed fire on habitat of beaver (Castor canadensis) in Elk Island National Park, Canada.
Forest Ecology and Management. 239:200-209.
Fire, flooding, herbivory, and the effects of climate are all topical issues for today's land managers. Effective resource management requires a balance among these processes, which in turn, requires a better understanding of their interactions. Beaver (Castor canadensis) are strong colonizers and have been successfully reintroduced to much of their former range. Prescribed fire has also been introduced in many areas as a management tool to restore ecological function. Resource managers have often assumed fire would also benefit non-target species like beaver; however, its effect on beaver has not been well studied. In this study, part of a broader project in Elk Island National Park, Canada, we examine the effect of prescribed fire on beaver lodge occupancy in the context of high ungulate populations. Elk Island National Park has an active beaver population, high ungulate densities, and a well-established prescribed fire program. We examine whether frequency, size, and timing of bums influence beaver lodge occupancy and the establishment of new lodges. Since 1979, over 51% of the park (99.3 km2) has been burned with prescribed fire. By comparing lodge occupancy over a period prior to and after a series of prescribed bums, we analyzed beaver occupancy rates pre- and post-burn. Our results show that repeated burning dramatically decreases beaver lodge occupancy, and that even after one bum the number of active colonies declines and does not recover to pre-fire populations. Especially when combined with drought and herbivory, prescribed fire does not improve beaver habitat. [copyright] 2006 Elsevier B.V. All rights reserved.

Mitsch, W. J., J. W. Day and J. W. Day Jr. 2004.

Thinking big with whole-ecosystem studies and ecosystem restoration - a legacy of H.T. Odum. Ecological Modelling. 178:133-155.
Whole-ecosystem studies are in situ ecological studies and experiments of such a spatial and temporal scale as to include most if not all processes of the ecosystem. Principles of self-organization and self-design are key to whole-ecological function and often do not occur as vibrantly or conclusively at smaller scale experiments. Ecological feedback caused by organisms (e.g., beavers, plants that manage hydrology, ecosystem engineers, top-down control), pulses caused by events such as fire and floods, and emergent ecosystem properties caused by human wastes, recycling, and hydrologic modification are difficult if not impossible to be properly studied in small-scale experiments. Large-scale whole-ecosystem studies were pioneered in the 1960s and 1970s by H.T. Odum and colleagues with large drop nets in Texas coastal bays, rain forests enclosures in Puerto Rico, created coastal ponds in North Carolina, and sewage application to cypress swamps in Florida. The study in Florida investigated effects of wastewater additions to wetland function in cypress domes but unexpected fire in the experimental area led to adaptive research and the study of fire in field research and models. More recently we have been engaged in whole-ecosystem experiments, partially inspired by the work of Odum, at created wetlands in northeastern Illinois to investigate effects of water turnover on ecosystem function and in Ohio to provide insight on the long-range large-scale effects of hydrology and macrophyte planting on ecosystem function. We have also carried out major ecosystem-scale studies in coastal Louisiana, investigating the value of these ecological systems in treating wastewater and restoring lost landscape in coastal Louisiana. These studies in the Midwest and Mississippi delta form the basis of determining design standards on creating and restoring wetlands in the Mississippi River Basin to reduce the Gulf of Mexico hypoxia and regain many lost ecosystem functions over a large part of North America. [copyright] 2004 Elsevier B.V. All rights reserved.

Nienhuis, P. H., J. P. Bakker, A. P. Grootjans, R. D. Gulati and V. N. De Jonge. 2002. The state of the art of aquatic and semi-aquatic ecological restoration projects in the Netherlands. Hydrobiologia: the international journal on limnology and marine sciences. 478:219-233.
The Netherlands are a small, low-lying delta in W. Europe (42 000 km2; 50[degree]-54[degree] N; 3[degree]-8[degree] E), mainly consisting of alluvial deposits from the North Sea and from the large rivers Rhine and Meuse. The country was "created by man". The conversion of natural aquatic and terrestrial ecosystems into drained agricultural land was a major cultural operation over the past 1000 years. Roughly 55% of the country"s surface area is still agricultural land. Some decades ago, The Netherlands" landscape was characterised by an armoured coastline and bridled estuaries, a drastically reduced area of saline and freshwater marshes, fully regulated rivers and streams, and numerous artificial lakes. The aquatic ecosystems beyond the influence of the large rivers, the Pleistocene raised bogs and moor lands, have almost been completely annihilated in the past. Acidification and eutrophication led to the deterioration of the remaining softwater lake vegetation. Last but not least, an artificial drainage system was constructed, leading to an unnatural water table all over the country, high in summer, low in winter. Only very recently, some 25 years ago, the tide has been turned and ecological rehabilitation and restoration of disturbed ecosystems are in full swing now, enhanced by the European Union policy to set aside agricultural land in the Netherlands in favour of the development of "nature". The state of the art of aquatic and semi-aquatic ecological restoration projects in the Netherlands is given. Starting from the conceptual basis of restoration ecology, the successes and failures of

hundreds of restoration projects are given. Numerous successful projects are mentioned. In general, ecological restoration endeavours are greatly benefiting from progressive experience in the course of the years. Failures mainly occur by insufficient application of physical, chemical or ecological principles. The spontaneous colonisation by plants and animals, following habitat reconstruction, is preferred. But sometimes the re-introduction of keystone species (e.g. eelgrass; salmon; beaver) is necessary in case the potential habitats are isolated or fragmented, or when a seed bank is lacking, thus not allowing viable populations to develop. Re-introduction of traditional management techniques (e.g. mowing without fertilisation; low intensity grazing) is important to rehabilitate the semi-natural and cultural landscapes, so characteristic for the Netherlands. For aquatic ecosystems proper (estuaries, rivers, streams, larger lakes) the rule of thumb is that re-establishment of the abiotic habitat conditions is a pre-requisite for the return of the target species. This implies rehabilitation of former hydrological end geomorphological conditions, and an increase in spatial heterogeneity. The "bottom-up" technique of lake restoration, viz. reduction in nutrient loadings, and removal of nutrient-rich organic sediment, is the preferred strategy. The "top-down" approach of curing eutrophicated ecosystems, that is drastic reduction of fish stock, mainly bream, and introduction of carnivorous fish, may be considered as complementary. For semi-aquatic ecosystems (river-fed and rain-fed peat moors, brook valleys, coastal dune slacks) it also counts that the abiotic constraints should be lifted, but here the species-oriented conservation strategy, the enhancement of the recovery of characteristic plant and animal species, is mainly followed. An important pre-requisite for the rehabilitation of the original natural or semi-natural vegetation is the presence of viable seed bank. Restoration of salt-marsh vegetation has to deal with a short-lived persistent seed bank, which means that transport of seeds by water currents is important. Isolated softwater ecosystems may rely on the long-lived seeds of the aquatic macrophytes. The paper ends with some notes on the predictability of the outcome of ecological restoration measures and the societal position of restoration ecology as a science. Scientists hold different views on the predictability of restoration measures. A fact is that the predictability of ecosystem development increases, with increasing knowledge of the underlying environmental processes.

Perkins, T. E. and M. V. Wilson. 2005.
The impacts of Phalaris arundinacea (reed canarygrass) invasion on wetland plant richness in the Oregon Coast Range, USA depend on beavers.
Biological Conservation. 124:291-295.
Invasive plants can threaten diversity and ecosystem function. We examined the relationship between the invasive Phalaris arundinacea (reed canarygrass) and species richness in beaver wetlands in Oregon, USA. Four basins (drainages) were chosen and three sites each of beaver impoundments, unimpounded areas and areas upstream of debris jams were randomly chosen in each basin for further study ($n = 36$). Analysis of covariance (ANCOVA) showed that the relationship between Phalaris and species richness differed significantly ($p = 0.01$) by site type. Dam sites (beaver impoundments) exhibited a strong inverse relationship between Phalaris and species richness ($b_D = -0.15$), with one species lost for each 7% increase in Phalaris cover. In contrast, there was essentially no relationship between Phalaris cover and species richness in jam sites (debris jam impoundments formed by flooding; $b_J = +0.01$) and unimpounded sites ($b_U = -0.03$). The cycle of beaver impoundment and abandonment both disrupts the native community and provides an ideal environment for Phalaris, which once established tends to exclude development of herbaceous communities and limits species richness. Because beaver wetlands

are a dominant wetland type in the Coast Range, Phalaris invasion presents a real threat to landscape heterogeneity and ecosystem function in the region. [copyright] 2005 Elsevier Ltd. All rights reserved.

Pinay, G. and R. J. Naiman. 1991.
Short-Term Hydrologic Variations and Nitrogen Dynamics In Beaver Created Meadows.
Archiv fur Hydrobiologie. 123:187-205.
Beaver (Castor canadensis) alter the structure and dynamics of aquatic ecosystems through their dam building and feeding activities. The environmental heterogeneity in beaver-created meadows and wetlands was assessed over distance, soil depth, and time in Voyageurs National Park, Minnesota. The influence of aerobic and anaerobic boundaries on nitrogen availability in beaver-created meadows was also investigated. Short-term fluctuations of the hydrological regime enhanced sediment nitrogen dynamics and nitrogen availability for plant growth in an otherwise impoverished boreal environment. These natural water level changes sustained beaver wetlands and meadows in a loose equilibrium where imposed deviations of the environmental conditions tended to remain within fixed upper and lower bounds, but did not appear to have preferred values. Such dynamical equilibrium in beaver-created meadows for aerobic-anaerobic status at the scale of a few meters sustained the structure and dynamics of sedge and grass vegetative patches occurring between pond and upland zones at the landscape scale. Similar patterns of nitrate availability occurred in the active pond and in the abandoned pond. This similarity between active and abandoned ponds suggests that environmental processes occurring during stream impoundment have a long term effect on sediment structure and functioning, affecting the pond long after it was drained.

Pollock, M. M., G. R. Pess and T. J. Beechie. 2004.
The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA.
North American Journal of Fisheries Management. 24:749-760.
The use of beaver Castor canadensis ponds by juvenile coho salmon Oncorhynchus kisutch and other fishes has been well established. However, the population-level effects on coho salmon resulting from the widespread removal of millions of beaver and their dams from Pacific Coast watersheds have not been examined. We assessed the current and historic distributions of beaver ponds and other coho salmon rearing habitat in the Stillaguamish River, a 1,771-km2 drainage basin in Washington and found that the greatest reduction in coho salmon smolt production capacity originated from the extensive loss of beaver ponds. We estimated the current summer smolt production potential (SPP) to be 965,000 smolts, compared with a historic summer SPP of 2.5 million smolts. Overall, current summer habitat capacity was reduced by 61% compared with historic levels, most of the reduction resulting from the loss of beaver ponds. Current summer SPP from beaver ponds and sloughs was reduced by 89% and 68%, respectively, compared with historic SPP. A more dramatic reduction in winter habitat capacity was found; the current winter SPP was estimated at 971,000 smolts, compared with a historic winter SPP of 7.1 million smolts. In terms of winter habitat capacity, we estimated a 94% reduction in beaver pond SPP a 68% loss in SPP of sloughs, a 9% loss in SPP of tributary habitat, and an overall SPP reduction of 86%. Most of the overall reduction resulted from the loss of beaver ponds. Our analysis suggests that summer habitat historically limited smolt production capacity, whereas both summer and winter habitats currently exert equal limits on production. Watershed-scale restoration activities

designed to increase coho salmon production should emphasize the creation of ponds and other slow-water environments; increasing beaver populations may be a simple and effective means of creating slow-water habitat.

Syphard, A. D. and M. W. Garcia. 2001.
Human- and beaver-induced wetland changes in the Chickahominy River watershed from 1953 to 1994.
Wetlands. 21:342-353.
Historically, anthropogenic activities have contributed to the direct loss of wetland area, mostly due to agriculture and urban land uses. Urbanization also indirectly impacts wetlands at a landscape scale through altered wetland hydrology and change in the spatial configuration of wetlands in a watershed. In addition, beaver (Castor canadensis) create and modify wetlands in a landscape. Because of recent increases in urbanization and rising beaver populations, a raster-based geographic information system (GIS) was used to analyze the combined effects of humans and beavers on wetland area and types in the Chickahominy River watershed from 1953 to 1994. Results of the study revealed that 29% of the land changed during the 41-year study period, and wetland conversion constituted seven percent of the total change. The major reason for wetland loss was the construction of two large water-supply reservoirs in the watershed, and most of the remaining wetland loss was due to urbanization. Wetland functions vary depending on wetland type, and the results of this study showed that 90% of the change in wetlands from 1953 to 1994 was a result of shifting between wetland types. Beaver-modified wetlands increased 274%, and beaver activity was responsible for 23% of the wetland change.

Wilkinson, T. 2003.
The benefits of beavers.
National Parks.
Beavers were considered extinct in the beginning of the 20th century. Their comeback in the United States and Canada is considered one of the greatest successes of conservation programs. These large industrious rodents create wetlands and marshy areas that provide habitat for hundreds of species. Beavers are famous for their prowess at building dams and engineering wetlands. These shy aquatic mammals can be found in the national parks of Alaska and southwest towards the Rio Grande. They live in domed lodges and weigh about 65 pounds. They breed in winter and give birth to kits in the spring. These slow moving mammals live mostly in water and on land are vulnerable to predators. Beaver experts confirm that these animals were once abundant and suffered radical depletion due to commercial fur trapping. The decline in beaver population caused drying of wetlands and expansion of meadows and forests. With the efforts to enhance riparian habitat, beavers were reintroduced. They break up landscape and affect the homogeneity of species by producing aquatic habitat. Though beavers cause floods, their marshes protect adjacent landscapes from the effects of flash floods. Numerous bird species including songbirds, amphibians, reptiles, aquatic insects, and fish draw benefits from the presence of beavers. Beaver ponds and dams act as filters capturing silt and other impurities. They can challenge humans by toppling trees in city parks and backyards. The floods in basements, roads, and croplands caused by their handiwork result in severe property damage. As a nonlethal method of management, nontoxic chemicals are being used to repel these animals. Beavers scent-mark their territories and use unique ways of communication. They slap their flat tails against water surfaces as in alarm to intruders. Like wolves, beavers are cooperative

breeders. They feed on a variety of trees, preferably aspen. During spring and fall, when leaves are not available, they feed on tree bark and when their food supply becomes less, the colony moves on. Efforts should be made to understand their abundance, distribution, and critical habitat needs, which help in the recovery of these charismatic animals.

###