A BIBLIOGRAPHY OF BEAVER, TROUT, WILDLIFE, AND FOREST RELATIONSHIPS

with special references to beaver and trout

Technical Bulletin No. 137
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ABSTRACT

A total of 446 references to beaver (*Castor canadensis*) ecology and the relationships of beaver to trout, waterfowl and other wildlife, and forests are presented. Annotations of 36 papers selected from the general references deal specifically with the relationship of beaver and their activities to wild trout in low to moderately high gradient streams in Wisconsin (10), Michigan (9), Minnesota (10), New York (5), Maine (2), Massachusetts (1), and Ontario (1).

COVER: *Beaver ponds such as this may increase the local density of furbearers and waterfowl, but on low gradient streams common to northern Wisconsin will ultimately destroy the wild brook trout population*

A Bibliography of Beaver, Trout, Wildlife, and Forest Relationships

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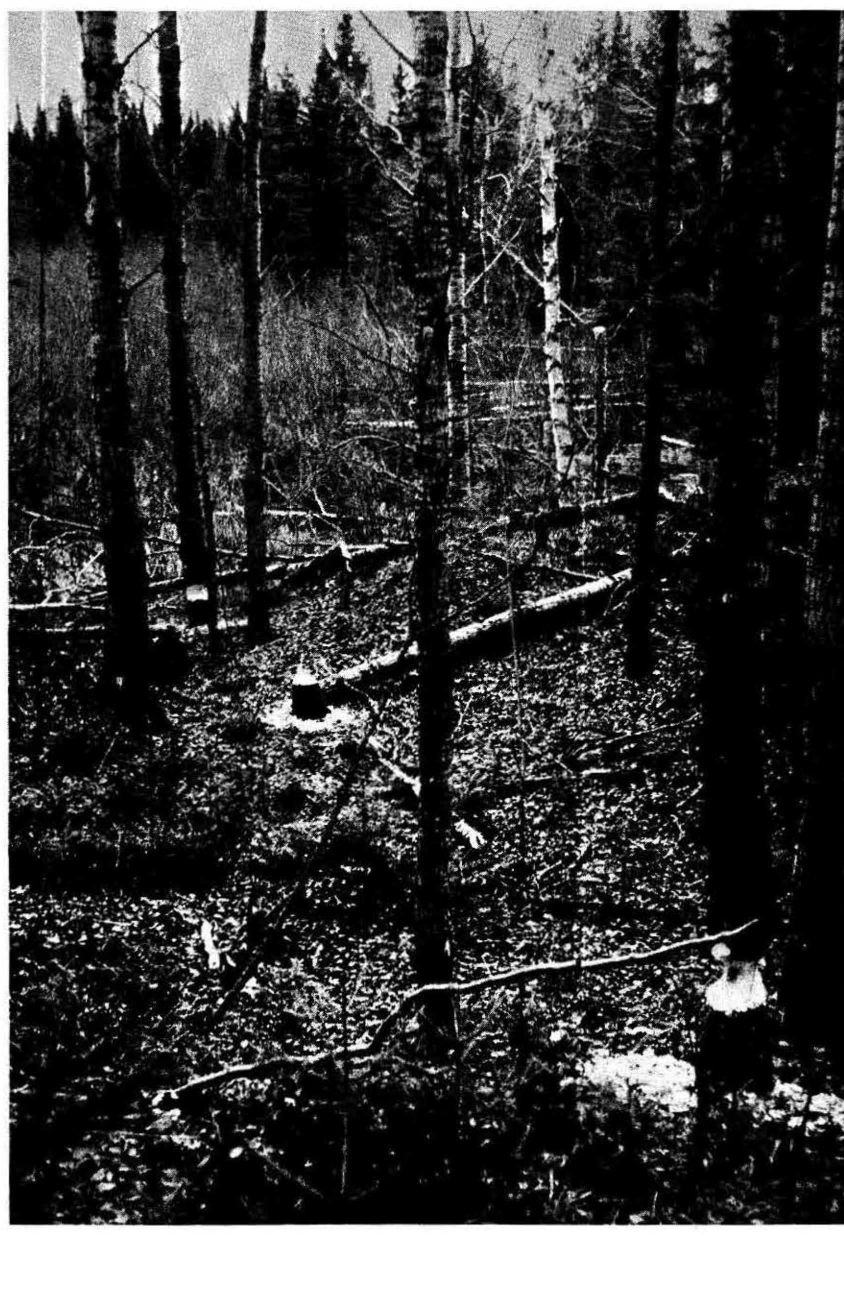
INTRODUCTION

The degradation of trout habitat by beaver is considered a severe threat to wild trout management in Wisconsin. Beaver impoundments serve as heat collecting units in summer and cold storage units in winter, markedly affecting survival of resident trout. Such impoundments often lead to the buildup of fish that compete with trout for food and space (e.g., suckers, chubs, daces and shiners). Higher fish densities in the impounded areas also attract greater numbers of avian and mammalian predators and increase the likelihood of fish parasites and disease. Decreased water velocities and the sloughing of inundated stream banks within impounded stream segments contribute to the siltation of former gravel riffles used for food production and trout spawning.

When beaver move out of an area and the dam is breached allowing the impoundment to drain, a wide, shallow channel flowing through dead timber remains. Stream velocities are not sufficient to cut through silt deposits and re-establish a pool-riffle complex similar to that present before impoundment. Stream water temperatures remain higher than before impoundment because of the wider stream channel and lack of forest canopy for shade.

All of the above effects of beaver on trout streams have been observed but quantitative documentation is very rare or nonexistent. The Department of Natural Resources has set up a study to quantify the effects of beaver dams and their impoundments upon trout streams and the response of these streams to the removal of such dams.

The first step in this study was a literature search to key new research to those areas where quantitative support is most crucial to proper management of the trout resource. The bibliography will also provide fish managers with a current, readily accessible reference library on the ecology of beaver and their relationships to trout, waterfowl and other wildlife, and forests. References listed range from technical documents to general discussions and recollections, but particular attention is given to studies directly applicable to stream environments found in Wisconsin.



*Forestry losses not only result from the flooding of merchantable timber by beaver dams but also from the direct cutting of 3,000 to 4,000 acres of aspen (**Populus tremuloides**) per year by beaver.*

GENERAL REFERENCES

This section addresses all of the relationships between beaver and forests, fish, waterfowl and other wildlife, with an emphasis on beaver ecology. There are 446 references, alphabetized by author. A subject index follows the bibliography to direct the reader to papers addressing one or more specific topics. References listed a second or third time in the index are italicized.

Papers housed at the Wisconsin Department of Natural Resources Technical Library in Madison are designated by a (T) following the reference, and include 114 of the 446 references listed. An additional 125 papers are available in the Wildlife Ecology Library on the University of Wisconsin-Madison campus and are indicated with a (W).

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SUBJECT INDEX

*References listed a second or third time in the index are italicized.

**Several papers indexed under this heading contain information relative to beaver life history. Because of their broad subject matter, however, they are not listed in the "Life History" subject headings.

A large beaver dam once impounded this small brook trout stream and is responsible for changing it from a narrow, cool stream flowing through lowland timber to what you see here—a wide, sluggish stream flowing through a broad meadow. The stream now supports few trout because of high water temperatures and poor habitat.

ANNOTATED REFERENCES (Beaver-trout relationships on low to moderately high gradient streams)

The annotated references deal specifically with the relationship of beaver and their activities to wild trout and trout streams similar to those found in Wisconsin, Minnesota and Michigan. There are 36 annotated references alphabetized by author. They are numbered to correspond to their citation in the General References, where the complete reference is given. The limited number of annotations reflects a paucity of quantitative information relative to the specific impact of beaver activities on trout habitat and trout populations. Papers of particular interest because of the quantitative data they contain are marked with an asterisk (*) at the beginning of the reference. In the case of several lengthy papers, information provided in the annotation is that relative to the subject. Two references were not available to me, but are included in the annotated bibliography because of their apparent relevance to the beaver-trout issue on low gradient streams.

1. **Adams (1949)** — A popularized article dealing with the controversy surrounding beaver management in Michigan, the need for data on which to base a management policy considerate of all interests, and the efforts of the Conservation Department to obtain such data. The latest effort to obtain information on beaver-trout relations involves a new research project headed by the author at the Hunt Creek Fisheries Experiment Station. It is an attempt to follow beaver-trout relations over a period of years to learn the changes in trout carrying capacity chargeable to the beaver. The study focuses on the Middle Branch of the Ontonagon River and a tributary of the Paint River. A brief synopsis of methodologies used and observations made the first summer of the study are discussed. Unanswered questions and several phases of the beaver-trout problem to be attacked in the future are suggested. No quantitative data are presented.

*2. **Adams (1952)** — Definite warming of streams in their passage through either a long pond or a series of dams is demonstrated. Beaver pond water exhibited a definite loss of oxygen as revealed by biochemical oxygen demand tests in the field. Catch rates (catch/hour) varied little between the open waters of Ontonagon River and a headwater beaver pond on nearby Morrison Creek; but on Hunt Creek catch rates behind dams were considerably better than the overall average of the stream. In time, many Michigan beaver ponds became dominated by creek chubs rather than the favored brook trout; figures for the relative numbers of these two species, as obtained by different methods, are conflicting. A study on the barrier effects of beaver dams on normal trout movements was inconclusive, but it appears that the fish can pass over some dams at times of high water. Recovery of streams following beaver occupancy is a long-term proposition requiring more improvement than the removal of dams with dynamite. Good or bad effects of beaver dams on trout streams are related to the extent and duration of beaver occupancy, and to other local conditions, the most important of which are: the number of dams, the original bottom type, the ground water supply, the presence or absence of spawning beds above and below the ponds, and creek chub competition.

3. **Adams (1954)** — Not available to author.

40. **Beckbane (1922)** — Conclusions arrived at in this article resulted from 12 years of residence and 20 summers passed within the Adirondack Forest Reserves of New York state by the author. The first few years of impoundment benefitted the trout as water temperatures increased along with food supplies (bait fish, etc.). Each successive generation of beaver moved upstream or downstream to build other dams and increase the height of old ones. Finally, the entire stream was blocked both up and down. Water temperatures increased and trout had to move or die. The author found large numbers of dead trout in various beaver flows in August and cited another individual who found 8 dead trout (4-12 inches) in another beaver flow on a stream flowing into the Cedar River. Predation on trout eggs and fry by immense quantities of minnows, chubs and horned dace and, in many beaver flows visited, small perch, sunfish, and bass accounted for the absence of small trout. The author described conditions on some New York streams and rivers which he fished. Numerous dams preventing free passage of trout, dead trout found on the aprons of dams, and other detrimental characteristics attributable to the beaver are discussed.

63. **Bradt (1947)** — Chapter 6, Beaver vs. Trout Controversy, contains the only information pertinent. The basis for developing a beaver-trout management program evolved from a vociferous group of complainants — the trout fishermen. J. C. Salyer of the Institute for Fisheries Research gathered facts during 1933-34 upon which to base such a program. Excerpts from Salyer's report are presented in this chapter. An emergency 15-day beaver trapping season was initiated in the fall of 1934 and again in the spring of 1935 to reduce beaver populations before inaugurating a system of control. Over 5,000 beaver dams were removed between 1934 and 1936. The results of these efforts are still the subject of controversy. The only conclusion stated was that beaver dams are detrimental to trout fishing on sluggish streams, and beneficial in certain types of rapid streams. "However, beaver dams are rarely beneficial to trout after the first two or three years, and often become distinctly detrimental if allowed to remain for long periods. Enough exceptions to these conclusions occur, however, to prevent them from being accepted by all fishermen." The only quantitative information presented is from Salyer's report published in 1935.

77. **Bump (1941)** — General history of the beaver population in New York and the use of trapping and transplanting as management techniques for population control are discussed. Nine liabilities and seven assets of beaver are presented that must be considered in a management program. No quantitative data are presented.

78. **Bump and Cook (1941)** — Following the history of beaver in New York, this paper lists nine problems which followed the train of beaver reintroductions in the state. No attempt is made to quantify the problems. The sixth problem was "Reduction in the productivity of slow-moving trout waters through the elimination of spawning grounds, the smothering of trout eggs by silt, by decreasing the available oxygen in the ponds, by raising water temperatures, and through the barrier effect of beaver dams." A list of seven benefits resulting from an increased beaver population is also given.

91. **Cook (1940)** — Comments are based on two decades of general observation made throughout New York. A brief synopsis of the life histories and ecological requirements of brook trout, brown trout and beaver is presented, followed by a discussion of the effects of beaver on trout habitat and ecology. Potential effects of beaver activities on stream temperatures, dissolved oxygen, production of bottom insects, water regulation, trout movement, trout reproduc-

tion, and angler harvest of trout are discussed. The monetary value of the beaver pelt and the value of the beaver pond to black ducks, deer and other furbearers are mentioned. A concluding statement emphasizes that the activities of the beaver be fairly judged and that the animals be condemned as harmful to trout only on valid evidence. No supportive quantitative data are presented.

110. **Evans (1948)** — This study quantitatively documents that beaver ponds increase water temperatures on North Shore trout streams in Minnesota. Of 10 ponds checked on 8 different streams, 8 had higher temperatures at the outlet than at the inlet. Increases of 6 F or more occurred in 7 instances. Outlet temperature of 4 ponds exceeded the lethal limit of 75 F for brook trout. Optimum temperatures of 68 F for brook trout were already exceeded on 4 ponds at the inlet and 9 at the outlet. In five cases, the ponds were responsible for temperatures above the brook trout optimum. Optimum temperatures for brown trout, 75 F, were exceeded on only 1 stream at the inlet and on 3 at the outlet. Considerable differences were found between surface and bottom temperatures with the latter usually favorable to trout. Little seepage of colder bottom waters through the dam was found. Maximum temperatures at the outlets were usually comparable to surface temperatures above the dams. "When ponds become so numerous as to eliminate shade from and impound fifty percent of a stream, the effect is definitely detrimental from the temperature standpoint."

The effects of beaver ponds on trout reproduction and migration, and the food production and fishability of streams are discussed. Contrary to studies in Michigan, there is no indication that Minnesota ponds became worthless for fishing in a short period. The value of beaver ponds to waterfowl in Minnesota and Michigan is discussed. On low gradient streams, beaver pond drainage was observed by the author to do more harm than good. Surface area was reduced only slightly while the main effect was reduced depth. Attempts to reestablish shade along streams have failed in Minnesota. "The above difficulties coupled with the obvious value of beaver ponds to waterfowl, the value of the beaver as a fur resource, and the value of ponds as reservoirs for use in fire control indicate the need for an extremely thorough analysis before dam removal is attempted for stream improvement purposes. In the Lake States where the problem is more important than elsewhere in the midwest, critical summer weather conditions prevail for relatively short periods. Unless heavy trout mortality occurs, frequently the cost of pond reduction can hardly be justified, particularly if all or some of the other values will be lost."

138. **Hale (1950)** — Investigations were carried out on the Caribou and Two Island rivers (both wild brook trout streams) and the Sucker River (a stocked brook and brown trout stream) to determine: if stocking of certain brook trout streams was necessary; if beaver ponds on trout streams have any value; and if intensive stream improvement work was beginning to show results.

Relative to the second objective, the catch of anglers fishing beaver ponds vs. the catch of anglers fishing the stream sections in both the Caribou and Two Island rivers were compared. Approximately 16% of all fishermen on each stream fished in beaver pond areas. Catch/man hour was higher in beaver ponds than in the remainder of the stream on the Caribou River (2.79 vs. 1.96). Similar results were noted on the Two Island River (2.12 vs. 1.71). The average size of brook trout caught in beaver ponds on both streams was more than an inch larger than trout caught in stream areas (7.25 inches vs. 6.15 inches).

A higher percentage of anglers fishing beaver ponds on both the Caribou and Two Island rivers were more successful at catching trout than anglers fishing the remainder of the streams. Beaver ponds on the Two Island River were older than those on the Caribou River leading to the speculation that differences in pond age may account for the difference in observed catch rates.

Beaver ponds on the Caribou and Two Island rivers did not appear to be a critical factor in warming the streams up to lethal levels for brook trout. A combination of ample shade and spring water below and above the ponds prevented this from occurring. Other studies of the effects of beaver ponds on water temperatures, insect fauna and riparian vegetation are discussed.

*139. **Hale (1966)** — This study was conducted on five North Shore streams with gradients of 40-42 ft/mile and discharges of 1-7 cfs. Fishing pressure was greater on streams with fewer beaver impoundments. On individual streams, a preference was shown for fishing in streams vs. beaver ponds. Trout from beaver ponds were of larger average size than those taken from stream areas. Standing crop in a stream with many beaver ponds on it was almost five times greater in the ponded areas than in stream areas, but poor natural reproduction and/or survival of young trout was documented. In a stream with few beaver impoundments, standing stock was similar in ponds and stream areas and natural reproduction was good. In another stream, the number of small trout was greatest under stream conditions and declined progressively during three stages of ponding, i.e., new pond, old pond inactive, old pond reactivated. In streams with many beaver ponds, large populations of minnows were present. In streams with few impoundments, the fish populations consisted primarily of trout and sculpins.

Impoundments raised water temperatures. Beaver dams appeared to act as barriers to fish movement and viability of trout eggs spawned below dams was low. Trout in beaver ponds were observed to occupy only the stream channel. Bottom fauna of ponds was greater than in stream sections but was comprised of less desirable food groups. Beaver dams are usually maintained for 3-5 years on the North Shore. Recovery of normal stream bottom fauna occurs in 1-3 years, but the return of upland vegetation on previously flooded areas is much slower. The flat beds of former beaver impoundments are usually covered with soggy, peaty soil that favors sedges and marsh plants. The soil water in them has a low pH and is high in ferrous iron, both conditions inhibitory to the establishment of upland vegetation which provides shade for the stream.

*140. **Hale and Jarvenpa (1950)** — This study involves aerial surveys and creel censuses of two North Shore streams. Catch/man hour was much higher in beaver ponds than in stream sections. Average size of brook trout from beaver ponds was much greater than the average size of trout from stream sections. Attempts to reestablish shade along beaver-damaged streams were failures. Studies in the United States and Canada relating beaver ponds to water temperature changes, changes in riparian vegetation, fish movement, spawning beds, and insect fauna are discussed. The following conclusions are based on all available

Minnesota evidence on beaver-trout relationships as well as studies conducted in nearby states: (1) 1.8 beaver ponds/mile on study streams; (2) immediate result of beaver establishment on most trout streams seems favorable for trout yield; (3) great temperature changes have not been noted due to impoundments; (4) as beaver ponds age, they deteriorate as trout habitats. Removal of shade trees and shrubs causes increase in water temperatures. Silting destroys spawning areas especially in small tributary streams which were once nursery areas. An aging pond is shallower, and trout are concentrated in small areas making them highly vulnerable to anglers. There is a net decrease in insect fauna preferred by trout as a pond ages and fills in; (5) presence of large numbers of beaver structures often renders man-made improvements inoperative; (6) creation of a beaver pond and inevitable succession of that pond into a grassy marsh greatly retards reforestation, shading and water retention. Many decades elapse between the time a colony moves away and the time that a new suitable trout environment can be developed.

153. **Haugstad (1970*a*)** — Effective methods were developed to control beavers and to restore beaver-damaged trout habitat in the low-gradient streams of east central Minnesota. About 75 miles of fair-to-good-quality trout waters were created by applying beaver control to 200 miles of stream. The beaver control project was operated for two years in which at least 617 beavers, 482 beaver dams, and numerous feed beds were removed. Later stream inspections found that about 50 beavers had survived in the controlled areas (200 miles), but only 8 remained in the suitable trout waters (75 miles). A progressive system of beaver control was used which included stream surveillance, professional trapping before the open season, open-season trapping, and final eradication by state workers with traps, firearms and dynamite.

The main trout habitat problems before the project were associated with: reduced shade, warmed waters, silted spawning and food-producing areas, poor bank cover, and poor channel characteristics. Trout population increases were significant one year after the project was started. In addition to the beaver control project, stream improvement projects completed between 1952 and 1969 on about 30 miles of trout streams in southeast and east central Minnesota are discussed and evaluated.

154. **Haugstad (1970*b*)** — This is a step-by-step approach to how to conduct a beaver control operation based upon the author's first-hand experience in conducting a two-year beaver control operation on 200 miles of low-gradient trout water in central Minnesota's Pine County. Methods to gain the support of the general public, the trapper, the local citizenry and riparian landowners are discussed. Techniques for removing beaver dams and feed beds are presented.

171. **Hine (1962)** — This popularized article focuses on recent management recommendations for beaver made by a special beaver-trout-forestry committee. A scenario of beaver-trout-forest relationships in Wisconsin is presented based upon the facts which guided the committee in making their management recommendations. The latter relies heavily upon intensive studies of beaver ponds recently completed by Wisconsin research biologist George Knudsen.

174. **Hodgdon and Hunt (1955)** — This paper deals with the description, life history, ecological relationship to man and other animals, and management strategies concerning beaver. Observations on brook trout relationships with beaver were made, but no special study of the problem was initiated because it appeared too time consuming. A case of a beaver flowage producing "many large trout (1 to 1 1/2 lb) for the size of the brook" is stated, but quantitative data are lacking. The dam had been intact for about 6 years and fishermen came from miles around to fish. Excerpts from a study by R. S. Rupp (1954) on Sunkhaze Stream in Penobscot County are presented. These excerpts depict volume production of insects in impounded areas and measurable, but not serious, reduction in water quality. Dams constituted a serious obstacle to upstream movement of trout but a lesser obstacle to downstream movement. The general tone of this paper is that the assets to wildlife resulting from the presence of beaver outweigh the liabilities in Maine.

183. **Hovind (1948)** — This study centers in Marinette County during the past 10 years. A total of 228 dams and flowages were checked. Sixty-five percent showed timber damage appraised at $11,617 (1,700 acres). Fires burned 4,342 acres but caused losses of only $7,442. Fires destroy less valuable trees. Beaver flowages caused loss of winter deer yards, damage to resort property by flooding and cutting of trees, loss of shade along streams (particularly trout waters), destruction of timber around spring holes and headwaters of streams, damage to farm lands and crops, and damage to highways. There is an additional loss of 300-400 cords of aspen felled by beaver for food annually in Marinette County. Damage in certain spruce areas of Minnesota is greater than the value of beaver fur produced in the same areas.

Michigan estimates that 25% of their mileage of trout streams becomes the bottom of beaver ponds every 10 years. Marinette County experienced timber losses along 35 miles of stream in 10 years. Fishermen report good catches of large trout in beaver flowages during the first few years of existence. After that, conditions usually become unfavorable for trout and good fishing is over in that particular stretch of water. Average length of time beaver use a dam is 4-5 years. There is little evidence that shows old flowages becoming restocked with valuable tree species as fast as new flowages are being made. It may take up to 100 years before some abandoned flowages become restocked with trees. Author suggests eliminating beavers from streams flanked by excellent growth of cedar, spruce and balsam. "A sound beaver management program should never lose sight that wood is a necessity and fur coats a luxury."

206. **Knudsen (1951)** — A popularized article describing the beaver, its habits, the benefits associated with its presence in the forest community, and the liabilities associated with too many beaver. No quantitative data are given.

208. **Knudsen (1959)** — A popularized article pointing out the benefits of beaver ponds to waterfowl, muskrats, mink, otter, raccoon, deer, black bear and woodcock. Also discusses the paradox of the relationship of beaver ponds to trout and other wildlife; i.e., ponds increase in game production with age but are at their best for production of trout when they are new.

*209. **Knudsen (1962)** — During the period 1950 to 1958, 353 beaver ponds were visited and detailed observations were made of many ecological relationships between beaver and trout habitat, forests, and other wildlife species. A typical sequence of habitat alterations resulting from beaver impoundments involving four stages of floodplain change is described. During beaver impoundment (stage 2), the most rapid and pronounced habitat changes occur. Trout habitat is most seriously affected and timber is drowned while, at the same time, wildlife habitat is improved and wildlife is produced, often in abundance, on the beaver pond. Destruction of timber by flooding was considered negligible based on an average of 0.35 acre destroyed per beaver pond. When beaver populations are high, cutting may destroy 3,000 to 4,000 acres of timber (primarily aspen) per year. Pioneer trees cut by beaver are replaced rapidly by the more shade-tolerant dominants in the understories. By selecting aspen and thus favoring the growth of less palatable species, beaver are reducing the carrying capacity of their habitat for the future.

The findings of this study support conclusions in the literature that beaver impoundments on slow-flowing trout streams do much more harm to trout habitat than good. Beaver ponds were found to be excellent producers of important game species such as ducks and muskrats, and many other wildlife species were found to use beaver ponds much more readily and in greater densities than they used the floodplain either above or below the pond. Specific recommendations made by a special beaver-trout-forestry committee of Wisconsin Conservation Department personnel, based on the results of this study, involved a classification of areas in which beaver should be controlled in accordance with fish and forest management interests and areas in which beaver should be kept at optimum numbers.

225. **Lawrie (1921)** — Not available to author.

234. **Longley and Moyle (1963)** — This paper documents the history and economics of the beaver in Minnesota and the natural life history of beaver and various methods of beaver management in Minnesota. A section, "Beaver values, plus and minus, as related to management", includes discussion of the effects of beaver on trout streams. Brief summaries of studies by J. G. Hale (1966) on Minnesota North Shore trout streams, D. S. Shetter and M. J. Whalls (1955) on a Michigan trout stream, and G. J. Knudsen (1962) on Wisconsin trout streams are presented. No additional quantitative information on the effects of beaver on trout streams is given.

239. **Mattis (1980)** — This paper builds a case for beaver ponds on small brooks found in wilderness areas of northern Wisconsin, Michigan and Minnesota. Ponds allow small fish to attain larger sizes than in the stream proper. This article is based on the fishing experiences of the author. Spinning gear is recommended using a slow retrieve over the stream channel and a No. 1 or No. 2 spinner. Fishing in the rain is excellent.

*254. **Moyle (1951)** — Past tree plantings, mostly willows, had failed on beaver meadows and this investigation was undertaken to learn something about the chemistry of ground waters in such areas. Holes were dug with posthole auger and tiller's spade on old beaver meadows and near beaver dams. The water table was 0 to 18 inches deep, and soil at 18 inches deep was dryer than at the surface suggesting slow percolation. Peat layer was less than 1.5 ft thick and lay on rock fragments or clay. The vegetation of beaver meadows is described. No earthworms were present in the saturated soils of old meadows. Chemical characteristics (D.O., pH, Fe) are given for ponds and ground water. Ground waters had low D.O., low pH and high Fe content. These conditions are all unfavorable for growth of upland vegetation and even for lowland trees if exposed for extended periods.

287. **Patterson (1950)** — Beaver ponds increase water temperature in northeastern Wisconsin. An average increase of 8 F from inlet to outlet was recorded with a maximum increase of 19 F. On the Peshtigo, Oconto and Wolf rivers, anglers reported good trout fishing during the first 2-4 years after the primary dam was built, followed by rapid deterioration. Although many good-sized trout (15-16 inches) have been caught from beaver ponds, investigation has not revealed whether the fishing would be as good or better if ponds were not there. Beaver dams slow down stream flow causing an accumulation of silt and muck. This destroys spawning areas and smothers trout eggs. Dams may also present barriers to trout and interfere with spawning runs. No all-inclusive statements can be made concerning the effects of beaver ponds on trout water. In northeastern Wisconsin, many formerly cold feeder creeks have been plugged with dams to such an extent that some of the larger trout streams have become excessively warm. Numerous spring ponds have been changed into extensive flowages with angling success reported poorer each year.

*288. **Patterson (1951)** — Peshtigo River: Beaver dams were beneficial in providing good fishing in the flowages for 2-4 years. Beaver dams were detrimental in increasing water temperatures of feeder streams, depriving the main stream of cold water. Beaver dams destroyed immediate bank cover of feeders by flooding, destroyed normal stream conditions, created pond conditions which no longer provided good trout fishing, and changed soil conditions in beaver ponds so that natural reforestation is slow. Oconto River: Beaver flowages are increasing water temperatures. Fishermen report brook trout fishing prior to 1941 was very good. Fishing has since greatly deteriorated due to numerous beaver dams in spite of annual stocking of brook trout. Large areas of streamside vegetation have been killed and siltation of flowage areas is extensive. Wolf River System: A case history of the destruction of Ninemile Creek as an excellent brook trout stream to one which now carries few trout is presented. Beaver dams were the cause. Other observations: Increased water temperatures, siltation and the disappearance of trout are discussed in streams of northeastern and north central Wisconsin. Beaver dams trap northern pike (*Esox lucius*) in spring ponds where they clean out the trout population.

*310. **Reid (1952)** — This paper is the result of the author's observations and research in the central Adirondacks of New York (Whitney Park). Premier summer trout fishing in a famous spring hole on a tributary of Little Tupper Lake declined to zero within 5 years. In the 1/2-mile tributary, 14 beaver dams raised the water temperature 16 F. Water temperature at the mouth was 2 F warmer than the main stream which it was supposed to cool. Chubs and shiners were abundant in the tributary but trout were absent. In another lake tributary, beaver dams within the first mile barred trout from the upper reaches of the stream and the only gravel bottom suitable for spawning. Many 6-10 inch brook trout and a few up to 13 inches were found above the dams, but none of the 1 1/2- to 3-lb lake fish which should have been there. Numerous trout from 1 1/2 to 3 lb were taken in weirs several miles upstream after the beaver dams were removed. Effects upon natural reproduction were not studied. Fishing was much improved after the dam removals, however.

Other negative and positive effects of beaver on trout, waterfowl and the local economy (pelt price) are discussed. There was an accumulation of silt and sand in the stream as a result of large amounts of mud used in dam construction. Mats of woody debris remaining from old dams and feed beds held accumulations of silt and must be removed to enable the stream to scour down to the original substrates.

*320. **Rupp (1954)** — The study was conducted in the vicinity of five beaver dams within a 1/4-mile reach of the stream. The largest dam held a 3-ft head while others held from 0.5- to 1.5-ft heads. Estimated age of dams was 8-10 years. Beaver dams presented a serious obstacle to trout movements but were unimportant since spawning, shelter, feeding and wintering areas were well distributed throughout the stream. Estimated unit area production of bottom organisms was poorer in the beaver ponds than in the stream, but the beaver had so increased the bottom area that total production of the stream section was more than doubled. Forage fishes appeared to be more abundant in the beaver ponds than in the stream and constituted an unexpectedly high percentage of the food of 6-10 inch brook trout taken in the ponds. Measurable but not serious water quality reductions were found in and below the beaver pond; i.e, higher temperatures, higher CO_2, lower D.O. and lower pH. Numerous springs in the bottom of the Sunkhaze beaver ponds may have prevented the development of more adverse conditions.

*324. **Salyer (1935*a*)** — This paper summarizes research findings based on both observational and experimental methods in Michigan trout streams from September 1933 to September 1934. Beaver dams, regardless of size and age, reduced dissolved oxygen with effects ranging from the elimination of every living organism to essentially no effect. The pH of beaver ponds decreases with age and in several instances water was so acid that trout survival was doubtful. Bad physical-chemical conditions rendered trout from a number of streams unpalatable. Beaver impoundments of a half acre or more caused a rise in stream temperature from one to several degrees, but this was of secondary importance in the ultimate effects of beaver on trout waters. Cooling of spring water in early winter due to the increased exposure of the water to air was more serious, because it cooled the stream temperature below the "spawning threshold" in miles of brook and brown trout water. Suffocation of fish food organisms and previously spawned trout eggs occurs from silt deposition below beaver dams following high water or injudiciously blown dams.

Results of fish tagging showed that trout do not pass upstream over the ordinary dam. Survival of trout eggs within 400 yds below a beaver dam was poor due to silting and low dissolved oxygen of water from ice-sealed ponds. On the headwaters of one river studied, 3 years of beaver occupancy reduced available spawning area to 100 yds of suitable stream. Stream sections used repeatedly by beaver were generally permanently widened and made shallow with a persistent sandy sump after the dams were out. Other positive and negative aspects of beaver and beaver ponds included the following: (1) beaver ponds concentrated trout and increased predator pressure from herons, kingfishers, bitterns, turtles and water snakes; (2) parasites such as strigeids (black spot disease), gill lice and round worms become prevalent; (3) angler harvest of trout in beaver ponds increases during the first two years but by the fourth year is essentially nil; (4) beaver destroy trout lakes by raising water levels and changing the whole ecology of the lake; (5) a beaver pond during the first year supplies food, shade and cover superior to that of the natural stream, supplies at least 2 years of good fishing, is an effective winter abode for trout on certain shallow streams (before the onset of severe stagnation), and increases food production for some distance downstream on impoverished, especially sandy streams; (6) beaver ponds are indispensable in maintaining continuous trout fishing in rocky, short, high gradient streams flowing into Lake Superior; and (7) beaver create fishing where none existed before in tiny spring trickles dammed to form trout ponds. Suggestions for beaver trout management are given which include trapping, routine and systematized removal of beaver dams, and habitat improvement techniques.

325. **Salyer (1935*b*)** — The May-June issue (pp. 39, 47, 48) deals with beaver control by trapping. A spring season between March 5 and March 25 is recommended along with the rationale behind it. The season should never exceed 15 days in the Lower Peninsula. The July-August issue (pp. 55, 62-64) deals with control of beaver by blowing out dams and establishing minimum habitat requirements on trout streams. Beaver dams should be removed in the spring of the 5th year since the greatest utility of beaver ponds to both beaver and trout ceases after the 4th year of mutual occupation. If done correctly, complete recovery from the effects of the pond will occur within 10 years dating from the first year of pond existence.

The methods of removing dams are discussed. Recommendations include the following: (1) any time a dam is a barrier to successful spawning, it should be removed regardless of the time of year; (2) if dams are longer than 30 ft, a section 25-30 ft long should always be blown out, preferably at the point of the original stream channel; (3) keep one-third of the headwater tributaries clear of beaver activity; (4) blow every dam at least once in 4 years, and all inactive dams should be removed; (5) streams with little swamp reserve should be kept almost, if not entirely, clear of beaver ponds; (6) any dam impounding an excellent spring should be removed immediately as it will destroy the spring within one year; (7) streams with a long and continual history of beaver occupancy had best be given over completely to beaver as long as the food supply lasts, since they are beyond recovery for centuries, (8) dams on trout streams flowing through grassy savanna-type country should be kept very infrequent; and (9) dams on rivers with heavy flow can be left for years if they show no tendency to sod in and if there are spawning tributaries available to trout between dams. The above recommendations and conclusions apply in states such as Minnesota, Wisconsin and Michigan as a whole and to the lowland and glaciated streams of the New England states. They should not be applied to typical alpine beaver meadows in western mountains and the higher New England and other eastern mountain streams. Beaver are a definite asset in the latter cases.

340. **Shaw (1948)** — The author discusses the history of beaver in Massachusetts and their life history, administration and management within the state. The

only quantitative information relative to the beaver-trout controversy is in Section VII, "The Beaver—Friend or Foe". At the Sanctuary in Lennox, "the normal stream below the beaver ponds could support trout, whereas the ponds themselves were too low in oxygen (3.6 ppm) and too high in temperatures (72-76 F) for normal trout existence."

343. **Shetter and Whalls (1955)** — The reestablishment of the Fuller Creek dam (to impound 14.6-acre Fuller Pond) raised midsummer water temperatures from 6.5 F to 10.1 F. The effect of the dam on midwinter average daily water temperatures was obscured partially by significantly higher average air temperatures in January and February of the 3-year post-treatment period (1949-51) combined with what is inferred to have been a significantly lower average discharge rate during the post-treatment period. No change in angling quality for brook trout based on catch/hour occurred, probably because temperatures even after the increase were well within the limits of physiological tolerance by brook trout.

348. **Smith and Knudsen (1955)** — This paper deals primarily with the type and frequency of beaver complaints received during the mid-1930's through the late 1950's. Trout streams are the usual sites for fish complaints against beaver and beaver dams. Beaver also cause trouble for fish hatcheries by blocking, flooding and/or diverting water. No quantitative information is presented.

*355. **Sprules (1941)** — Summary:

(1) When a section of stream characterized by rubble bottom and a rapid flow was changed into a slow-flowing pool through flooding by a beaver dam, a net numerical decrease in the insect population resulted in the period immediately following the change.

(2) Ephemeroptera, Trichoptera, Plecoptera and miscellaneous Diptera groups were decreased in numbers while the Chironomidae were increased.

(3) Species dependent on lotic conditions were reduced in number or wiped out of the area completely following construction of the dam, while species typically associated with lentic conditions were introduced.

(4) The change in the insect population was correlated with decreased rate of flow of water and the physical factors associated with this such as increased depth, and deposition of sand and silt which filled the interstitial spaces on the rubble bottom.

359. **Stephansky (1950)** — No quantitative information is provided. This paper reiterates the types of complaints received by the Michigan Department of Conservation against beaver. The arguments of sportsmen and conservation administrators for and against beaver on trout streams are discussed. "In most instances, Michigan's beaver dams seem detrimental on slow streams, whereas on faster waters they may be a decided aid in trout production. Beaver generally establish themselves on the slow streams in most areas. That is where most of the damage occurs from the work of nuisance beavers."

393. **Wilde, Youngberg, and Hovind (1950)** — This study was conducted in Marinette County, Wisconsin in 1947-48. Following removal of a beaver dam, the area is invaded by sedges (*Carex* spp.) and related marsh plants. On coarse sandy soils, aspen and paper birch move in after a few years. On peat or muck soils, sedge meadows resist reinvasion of forest for several decades. Plant succession on loam and clay soils is intermediate. The establishment of aspen on fine textured soils is usually accompanied by balsam fir.

Under conditions of stagnation or sluggish drainage, the back water of the flowage acquires strongly acid reaction and loses most of its electrolytes. The ground water of previously flooded lands was deficient in oxygen and possessed a low oxidation-reduction potential. This indicates that removal of beaver dams drains the flowage only superficially but not internally. Extremely low negative values of the redox potential reveal an environment favorable for the development of anaerobic microorganisms whose metabolic by-products are highly toxic to other forms of life.

With deoxidation comes saturation of soil with toxic "swamp gases" including H_2S. H_2S reacts with ferric compounds in the soil to produce soluble ferrous iron which in turn "ties up" phosphorus in an insoluble form. In general, impoverishment of soil in available nutrients and its enrichment in growth-inhibiting substances are characteristic of flowage bottoms exposed by drainage.

Toxic substances generated in the soil by inundated water cause a partial destruction of mycorrhizal fungi. The absence of the latter may be the major factor retarding the reinvasion of the drained flowage area by trees.

A rise in the ground water table depresses growth of forest stands on neighboring lowlands either by partial "drowning" of root systems or decreased aeration of soil; there is a limited benefit to neighboring uplands. When a dam is removed, the alteration of the ground water causes greater damage than flooding. The rapid change in ground water level creates danger of drought injury and generally decreased the growth of affected forest stands on both upland and lowland sites.

It appears more advisable to spend time and effort in preventing settlement of the beaver colony in undesirable locations rather than in removing the established dam.

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