Chapter III

Biological Implications

The operational schemes for New York City reservoirs in the Upper Delaware River Basin have upset stream ecology, caused severe damage to or changed downstream fisheries, interfered with downstream water-based recreational uses, prevented stream water quality standards from being met and generally reduced the value of the major surface water resources in the basin.

Minimum conservation releases are made from Neversink Reservoir for long periods--almost continuously in some years. They are not adequate to maintain satisfactory water quality in the river. The low flow, in combination with inadequately treated waste water discharges, has made swimming unpleasant and damaged the stream fisheries.

On both the East Branch Delaware River and Neversink River, trout production is severely limited by the high water temperatures which occur in the summer as a result of low flows. During the winter, prolonged periods of low flows allow anchor ice to form around large stones in riffle areas reducing available space and interfering with aquatic food production.

Higher flows also are needed in the streams below the dams each spring to flush out accumulated sediment and other materials. In some years, spillway overflow is enough to accomplish this; but in others, a short-term high release is required. With increased conservation releases and occasional high flows, both streams could sustain much larger trout populations and provide significantly more fishing opportunities.

On the West Branch Delaware River, both cold and warm water fisheries have been almost eliminated by wide fluctuations in flows and temperatures resulting from low conservation releases and high directed releases to meet the Montague requirements. High water temperatures from the low conservation releases prevent development of good trout fishing while the large releases of much colder water to meet the 1954 Supreme Court Decree requirements prevent establishment of a warm water fishery and can cause fish kills. The large releases also cause high river levels and strong currents and make fishing almost physically impossible. With increased minimum conservation releases and proper regulation of high flows, the West Branch could be made into a productive coldwater fishery.

On the Delaware River, fish population shifts have occurred as a result of reservoir operations. The change is most evident in the upper reach from Callicoon to Hancock. This stretch formerly supported a warmwater fishery that has now been nearly eliminated. The large volumes of cold water released intermittently from Cannonsville Reservoir have changed the fish populations to species tolerant to cold water. However, their survival is endangered during non-drought years when large volumes of cold water are not released and stream temperatures increase. A high quality, stable coldwater fishery could be established in the upper reach with increased conservation releases. The warm water fishery downstream to Port Jervis and beyond would also benefit from higher, more uniform flows.

Documentation of Fish Kills

The size of the Delaware River and its major tributaries generally precludes the reporting and subsequent documentation of fish kills. In the past 10 years, reported fish kills for the Upper Delaware River and its major tributaries number less than 10 and there were apparently no documentations of any of those reports. For the past five years, small kills of brown trout have been reported (but not documented) in the West Branch Delaware River at the beginning of the summer reservoir release program.

This lack of documented fish kills in the Upper Delaware Basin prompted a request to both State employees involved in a thermal monitoring program and the general public to report the occurrence of a fish kill in the Upper Delaware Basin during the summer of 1975. On August 6, 1975, Departmental personnel were informed of the occurrence of a fish kill near Pea's Eddy in the East Branch Delaware River. Subsequent investigation revealed that several species of fish were involved (see Table below) and that the kill had occurred upstream from the reported site.

Species		Number
brown trout (*Salmo trutta*)		11
rainbow trout (*Salmo gairdneri*)		1
American shad (*Alosa sapidissima*)		12
common white sucker (*catastomus commersonnii*)		4
rock bass (*Ambloplites rupestris*)		4
fallfish (*Semotilus corporalis*)		4
sunfish (species unknown)		1
American eel (*Anguilla rostrata*)		1
	TOTAL	38

Examination of water temperature data for the East Branch Delaware River in the week preceding the kill indicated that the daily minimum water temperatures were over 77°F on August 2-5, at Centerville and on August 2-4, on the East Branch above Beaverkill. The condition of the fish indicated that thermal stress was the primary cause of mortality and the preceding temperature data bears this assumption out. Ironically, the Delaware River Master's records show that large coldwater releases (average: 655 cfs) were made from Cannonsville on the West Branch during the period when the fish kill was occurring in the East Branch, Delaware River. If the thirty-day provision had been in effect, there would have been no fish kill and the Cannonsville release would have been only 465 cfs.

While there is limited documentation of fish kills in the Upper Delaware Basin, it now appears that the State has the evidence which shows that the current New York City reservoir operational scheme contributes to and/or causes fish mortality in the Upper Delaware River Basin.

Thermal Tolerance and Thermal Shock Study

Since both fish and invertebrates are poikilotherms, they are directly affected by the ambient water temperatures. In the Upper Delaware Basin, these organisms must contend with high water temperatures and/or abrupt fluctuations in temperature over relatively short periods of time depending upon location. The fact that both conditions can cause direct or indirect mortalities prompted a short-term study by the research staff of the DeBruce Fish Laboratory, Livingston Manor, to review the available literature and to undertake any required laboratory experiments.

While the scientific literature contained numerous references for the temperature requirements of salmonids, it was clear that little information was available for the temperature requirements of both invertebrates and other species of fish and the thermal shock capabilities of all organisms. A summary of the available fish information is presented in Table 2.

Trout. The three trout species have relatively similar adult temperature requirements: brown trout (preferred: 54°-64 F, upper lethal: 71.6-77.9°F); rainbow trout (preferred: 51.8°-60.8°F, upper lethal: 77.0°F); and brook trout (preferred: 53.6°-64.4°F, upper lethal: 77.4°F). Subsequent laboratory work confirmed that the upper or incipient lethal temperatures for both brown and rainbow trout were 77°F at high acclimation temperatures. Trout are able to resist brief exposure to these temperatures, but cannot survive in them indefinitely. Where the daily minimum water temperature exceeds 77°F, trout would only be able to survive by seeking refuge in spring areas or tributary mouths. In 1975, daily minima above 77°F occurred at the following stations on the following dates:

East Branch Delaware River	Centerville	August 2-5
	E. Branch (above Beaverkill)	August 2-4
	E. Branch (below Beaverkill)	August 3-4
	Fishs Eddy	August 2-4
	Hancock	July 18-19
		August 2-5
Main Delaware River	Hancock	July 18-19
		August 1
	Lordsville	July 18-19
		August 1
	Long Eddy	July 20
		August 1-2
	Callicoon	July 7, 18-20
		August 1-3

	Narrowsburg	July 6, 11, 19-20, 24-26, 31
		August 1-6
	Lackawaxen	July 7, 18-20, 25-26
		August 1-7
	Barryville	August 2-6
	Port Jervis	August 3-6
Neversink River	Port Jervis	August 4

It is generally accepted that salmonids do not thrive or grow well above 70°F and that at these temperatures, most of the daily ration goes to metabolic maintenance. Below approximately 45°F, winter conditions take over with subsequent reductions in both feeding activity and growth. The growing season for trout appears to begin in early April and extend through late October or early November (approximately 180 days). The compilation of the temperature data for the Delaware River and its major tributaries indicates a substantial reduction in the trout growing season for several stations. It became clear that the continued existence of fishable trout populations in the East Branch below Harvard and at any of the main Delaware stations is exceedingly precarious under the present water release plan.

Another set of laboratory experiments revealed that trout were not susceptible to acute thermal shock (primary chill coma) in the range of 47°F-80°F. The lower thermal tolerance limit for rainbow and brown trout acclimated to 70°F is below 39°F. Therefore, it appears that direct mortality from "cold shock" is unlikely, even in the West Branch.

Smallmouth Bass. Available literature for smallmouth bass indicated that the thermal requirements for this species (preferred: 68.5°-70.3°F, upper lethal: 82.5°F). Experimental work by Bureau of Fisheries Special Studies personnel revealed that smallmouth bass fingerlings acclimated at 50°F survived at 80°F, but not at 85°F. Fish acclimated to 62°F had a partial survival at 85°F. Since upward acclimation is quite rapid, it would appear that the upper thermal tolerance limits will rarely be exceeded in the Delaware River system.

Smallmouth bass fingerlings are susceptible to acute thermal shock when exposed to rapid (over 20°F/hour) temperature reductions to values below or slightly above the lower thermal tolerance limit. Symptoms are paralysis and partial respiratory arrest. In the laboratory, fish at temperatures above the lower tolerance limit recovered, but in a stream they would almost certainly be swept downstream and/or devoured by predators. Because a rapid temperature reduction is required, acute thermal shock is likely to be an important factor only very near a fluctuating source of cold water (e.g., Stilesville).

Table 2. Upper thermal tolerances, temperature preferenda, spawning and hatching temperatures for certain species of fish occurring in the Upper Delaware River Basin.

SPECIES	DEVELOP. STAGE		APPROXIMATE ACCLIMATION TEMPERATURES (^{o}F) NOT KNOWN	41	50	59	68	77	86	ULTIMATE	REFERENCES
Rainbow Trout		Lethal			75.2						Black,1953
(Salmo gairdneri)	Adult	Prefer.	56.3	60.8	59.0	55.4	51.8				Garside & Tait 1958
			55.4								Ferguson, 1958
		Spawn	41.9-55.4								Raynor,1942
	Egg	Hatch	37.8-59.9								Embody, 1934
Brook Trout (Salvelinus fontinalis)	Adult	Lethal	79.9								Brett, 1944
			69.8								Bardoch & Bernstein, 1957
					75.2					77.4	Gibson & Fry, 1954; Black, 1953
	Adult	Max.	78.8-82.9								Bridges & Mullan 1958
	Adult	Prefer.	55.0								Strawn, 1958
			44.6-64.4								Leach, 1923
			57.2-66.2								Graham, 1949
			53.6 (46.4 in winter months)								Sullivan & Fisher 1953
			57.2-60.8								Ferguson, 1958
Brown Trout	Adult	Lethal		72.5	75.2		76.6			77.5	Strawn, 1958
(Salmo trutta)				71.6	73.4		73.4				Bishai, 1960
			80.6-84.2 (Summer)								Grudniewski, 1961; Sakowicz & Stegman, 1961
	Adult	Prefer	54.3-63.7								Spaas, 1961
											Ferguson, 1958
	Alevin	Lethal	77.9								Spaas,1961
	Fry	Lethal		72.5			73.4				Spaas, 1961
	Yrlg.	Lethal	78.8								Bishai, 1960
	Parr	Lethal	84.2								Spaas, 1961

SPECIES	DEVELOP. STAGE		APPROXIMATE ACCLIMATION TEMPERATURES (°F) NOT KNOWN	41	50	59	68	77	86	ULTIMATE	REFERENCES
Smallmouth Bass (*Micropterus dolomieui*)	Adult	Prefer.	68.5-70.3								Ferguson, 1958
		Spawn	61.0-64.9								
		Lethal	82.4								
American Shad (*Alosa sapidissma*)	Adult	Lethal								97.7	Strawn, 1958
	Egg	Spawning	51.8-57.2								Svetovidov,1963
			59.0-62.6								Massmann, 1952
			53.6								Leim, 1924
			53.6-66.2								Mansueti, 1955
		Hatch	53.6-75.2								Bean, 1903; Hildebrand,1963; Leim, 1924; Mansueti, 1955; Svetovidov 1963
White Sucker (*Catostomus commersoni*)	Adult	Lethal		78.8-79.2							Hart,1947; Strawn, 1958
					81.9-82.4						Hart, 1947
						84.7					Strawn, 1958
							84.7-88.2				Strawn, 1958; Hart, 1947
											Strawn, 1958
								84.2-84.7			Brett, 1944; Strawn, 1958
		Prefer	66.2-69.8								Trembley, 1960
	Egg	Hatch	56.5-64.4								Bassett, 1957

Lower thermal tolerance limits for juvenile smallmouth bass are commonly exceeded in the West Branch of the Delaware River below Cannonsville Reservoir. At acclimations in the $70^{\circ}F-80^{\circ}F$ range, this occurs whenever the temperature drops more than about $27^{\circ}F$. The drop need not be sudden. Median resistance time at temperatures in high 30's and low 40's is about 65 hours, but appreciable mortality can occur within 24 hours. Death is from secondary chill coma, probably involving osmotic failure. Events in which the temperature drops below the lower thermal limit for acclimation and stays there for three or more days would be clearly lethal. Analysis of temperature records from the West Branch shows that a more typical situation is one in which the temperature stays below the lethal limit during most of a 24-hour period, but rises slightly above it during a brief part of the day, as indicated by the maximum recorded temperature. Repeated observations of lethally cold temperatures during early afternoon at the Stilesville and Deposit stations indicate that the temperature rose into the zone of tolerance only briefly. Prolonged exposure to this type of regime would probably cause complete or near-complete mortality. Lethal temperatures at Hale Eddy may have occurred mainly during the night, with daytime temperatures rising into the lower part of the zone of tolerance. Probable lethal events occurred on the following dates in 1975:

Below Stilesville	July 2-6, July 9-14
	July 19 (partial), August 1-7,
	August 13-18, September 13-16.
Deposit	Same as above.
Hale Eddy	July 9-12, August 2-7, August 14-17.
Hancock	None.

Smallmouth bass have not been collected in recent years from the West Branch of the Delaware River between Cannonsville and Hale Eddy, including the latter station. The upstream limit in the 1975 survey was Balls Eddy, 4.8 miles downstream from Hale Eddy. A thermal regime characterized by repeated sudden decreases from relatively high acclimation temperatures was typical of the summers of 1974 and 1975. Release patterns at Cannonsville show great year-to-year variations. In 1969, 1970 and 1971, early summer temperatures would probably have been too cold to permit bass production. USGS data for other years show either repeated sudden temperature drops, as in 1975; or prolonged periods of massive cold water releases, neither of which would favor bass survival.

Survival of smallmouth bass at Stilesville or Deposit is unlikely under the present release pattern or any foreseeable modification. Upgrading of the coldwater fishery in this area is much more realistic than any attempt at bass restoration. Increased "conservation" flows would, however, have a moderating effect on acclimation temperatures. If these were coupled with less massive and sudden releases, conditions might become suitable for smallmouth bass at Hale Eddy and all downstream points.

American Shad. The American shad appears to have relatively high thermal tolerances, but a preferred temperature which may be closer to those for trout (upper lethal: 97.7°F). Chittenden (1972) found that young shad acclimated to 75°F could tolerate temperature fluctuations between 55°F and 79°F, including decreases at a rate of 7°F per hour. He noted that the ultimate lower thermal tolerance limit was about 36°F, but sluggish behavior and poor responses occurred below about 42°F. Tagatz (1961) found young shad to be extremely sensitive to small rapid temperature decreases and that at 70°F acclimation, the lower thermal tolerance limit falls between 45°F and 50°F. Thus, the lower limits for American shad appear to be quite similar to those for smallmouth bass.

There is little doubt that the West Branch of the Delaware River would have been unsuitable for shad in 1975. Lethal events for juveniles would be essentially the same as those for smallmouth bass. Temperatures below 52°F extended all the way to Hancock. Shad restoration below Hale Eddy would be conceivable if fairly high temperatures could be maintained in early summer (as in 1967 and 1972), and if fluctuations in late summer releases were moderated by a larger conservation flow.

Summary. The results from the 1975 research study in conjunction with the available literature have provided some of the baseline thermal information required for determination of optimal reservoir release flows. If the average daily summer water temperatures were not to exceed 77°F, except for very short periods of time, then the thermal stress problems currently occurring in the Upper Delaware Basin would be minimized and, possibly, eliminated except for very warm periods.

Impact on Fish Production

The biological production of a stream or river is dependent on a number of critical factors. The rate of flow and the wetted perimeter are two key factors because of their impact on temperature conditions, abundance and distribution of invertebrate fauna (food organisms), spawning areas, and cover. The current reservoir operations have markedly reduced the wetted perimeters in the East Branch Delaware River and the Neversink River and caused drastic fluctuations in the West Branch and main Delaware River, which, in turn, reduce invertebrate production and reproductive success of certain fish species. Therefore, the proposed continuous conservation releases are expected to have a significant impact on fish production in the Upper Delaware Basin. Estimates of the increases in wetted perimeter are currently being made for the affected sections of the Delaware River from the reservoirs to Port Jervis with various reservoir releases. Once these have been made, it will be possible to estimate the additional production of trout, shad and other species which can be expected from these new releases.

Potential Improvements

It is apparent that conservation releases from Cannonsville, Pepacton and Neversink Reservoirs need to be increased and a minimum flow maintained on the Delaware River at Callicoon to protect and improve the fishery. There also is a need to make larger releases from the three reservoirs during critical periods to alleviate stress conditions and to protect downstream fisheries. One day flushing releases from Neversink, Pepacton and Cannonsville Reservoirs may be needed during years when spillway overflows are not of sufficient magnitude to flush the stream. Releases from Cannonsville Reservoir to meet Callicoon and Montague requirements need to be made in a more graduated manner to avoid sudden changes in downstream environmental conditions.

With the improved flows, the following improvements are anticipated for the fishery resources:

- extension of suitable trout habitat and improvement in juvenile shad habitat between the section Corbett to East Branch on the East Branch of the Delaware River (see Figure 4).

- extension of suitable trout habitat in the section between Deposit and Hancock, and possible restoration of juvenile shad habitat between Hale Eddy and Hancock on the West Branch of the Delaware River (see Figure 5).

- protection and enhancement of the trout, smallmouth bass and American shad fisheries on the main Delaware River.

- possible extension of the trout habitat into the section between Woodbourne and Bridgeville on the Neversink River (Figure 6).

Therefore, significant improvements are expected from the improved reservoir release schemes.

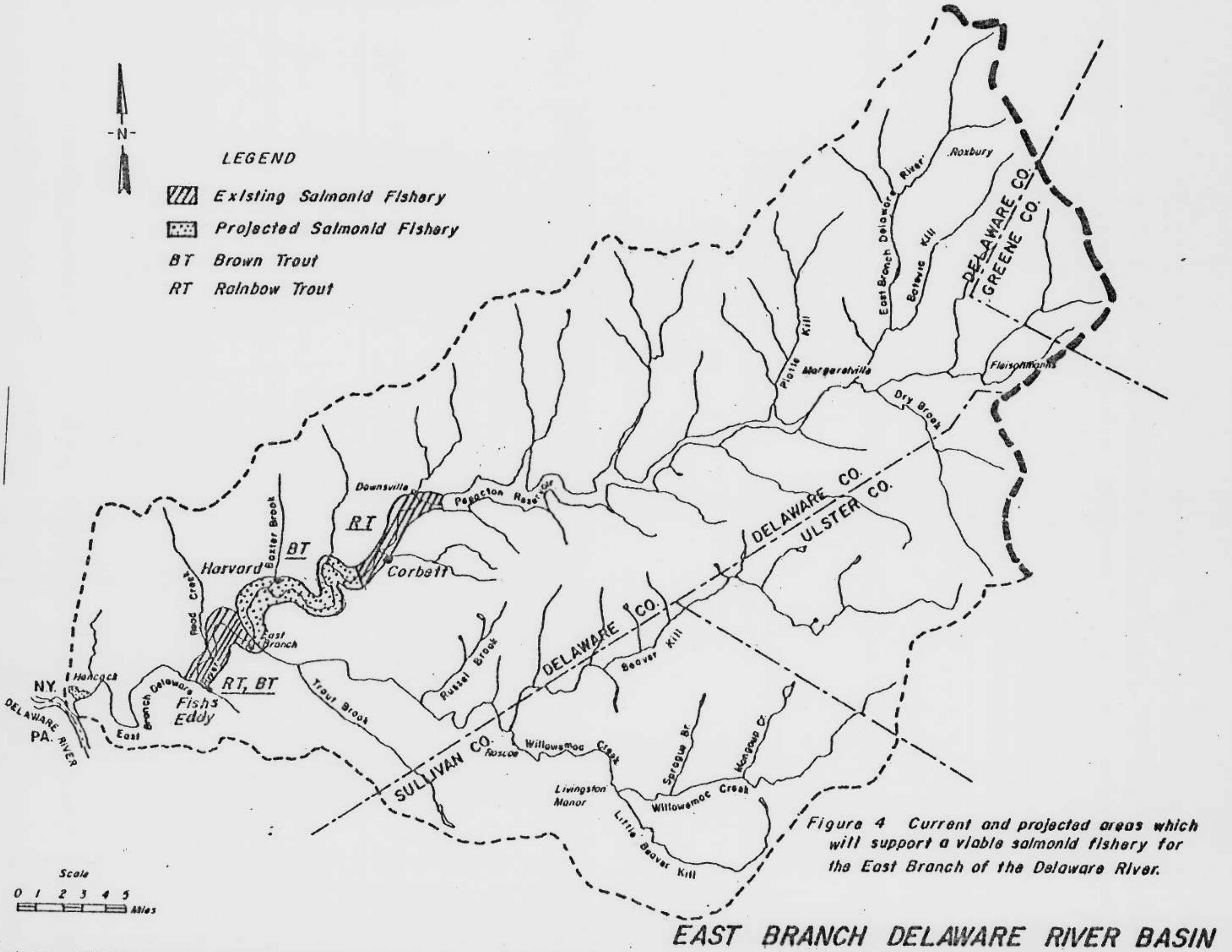
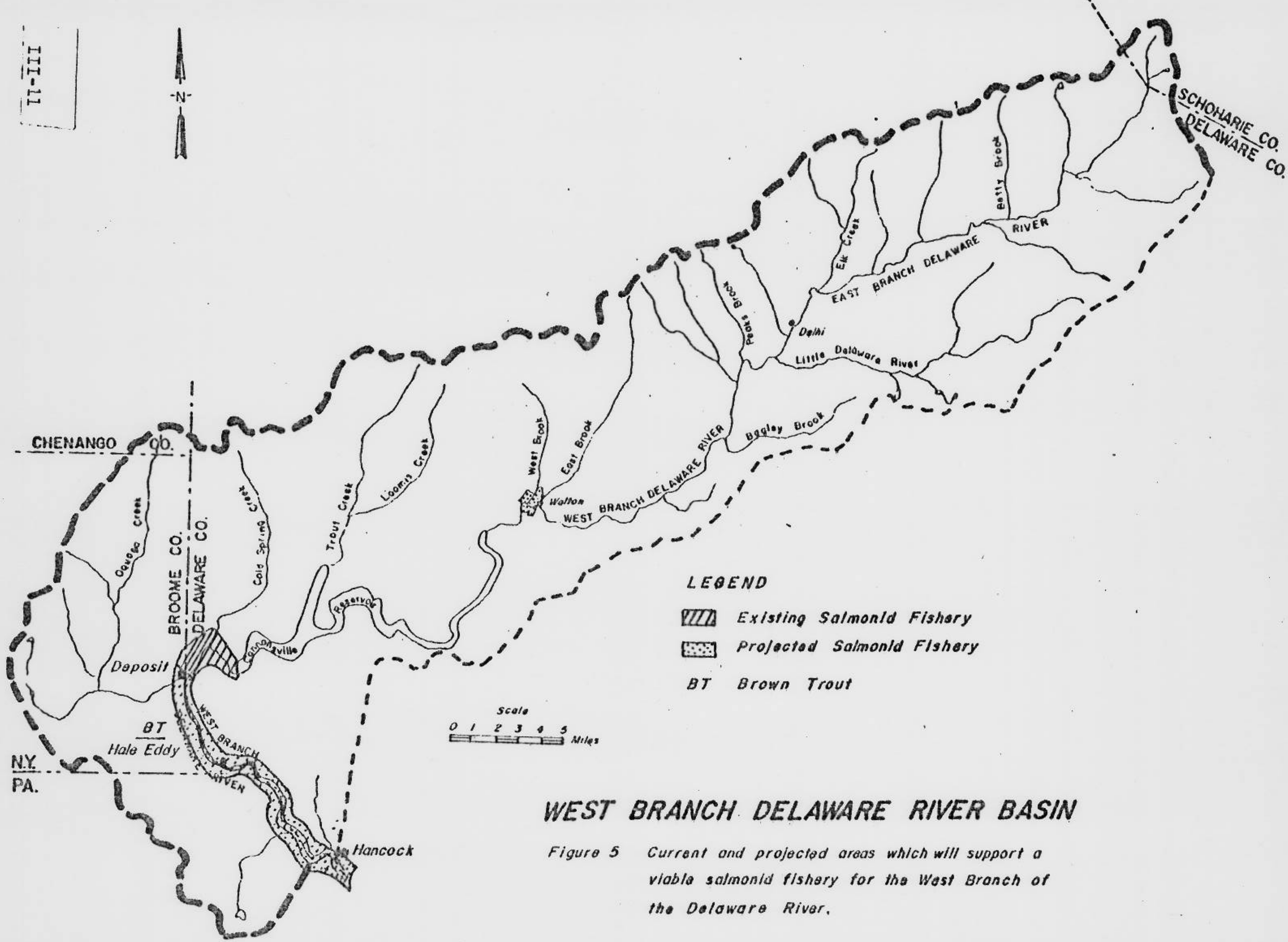


Figure 4 Current and projected areas which will support a viable salmonid fishery for the East Branch of the Delaware River.



WEST BRANCH DELAWARE RIVER BASIN

Figure 5 Current and projected areas which will support a viable salmonid fishery for the West Branch of the Delaware River.

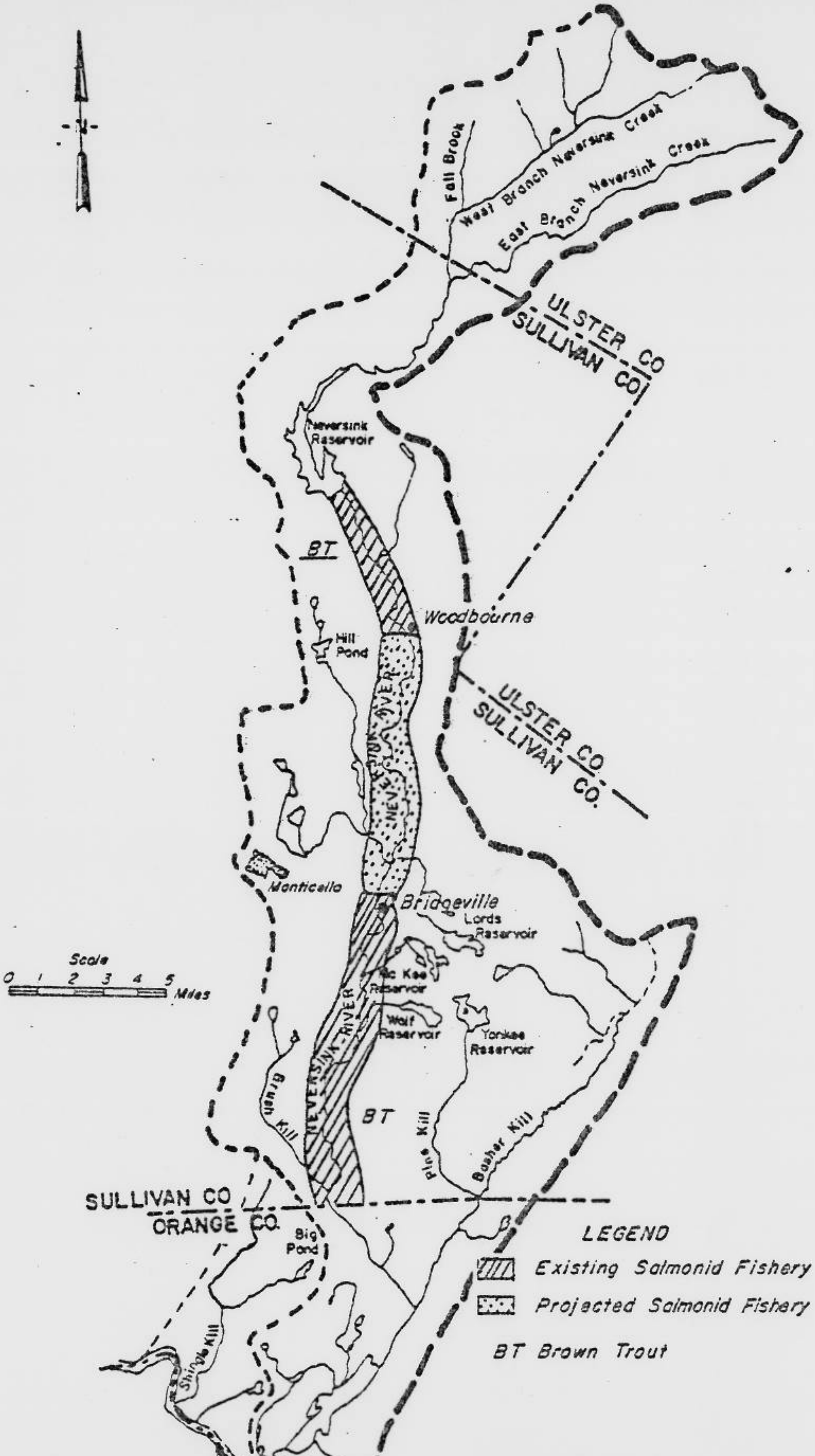


FIGURE 6

NEVERSINK RIVER BASIN

Current and projected areas which will support a viable salmonid fishery for the Neversink River.

Literature Cited

Bassett, H.M. 1957. Further life history studies of two species of suckers in Shadow Mountain Reservoir, Grand County, Colorado. M.S. thesis, Colorado St. Univ. 112 p.

Bardach, J.E. and J.J. Bernstein. 1957. Extreme temperature for growth and survival of fish. In "Handbook of Biological Data".

Bean, T.H. 1903. Catalogue of the fishes of New York. N.Y. State Mus. Bull., 60. 784 p.

Bishai, H.M. 1960. Upper lethal temperature for larval salmonids. J. Cons. Int. Explor. Merc. 25: 129-133.

Black, E.C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. J. Fish. Res. Bd. Can., 10: 196-210.

Brett, J.R. 1944. Some lethal temperature relations of Algonquin Park fishes. Publ. Ont. Fish. Res. Labs., No. LXIII. 49 p.

Bridges, C.H. and J.W. Mullan. 1958. A compendium of the life history and ecology of the eastern brook trout, *Salvelinus fontinalis* (Mitchill). Mass. Fish. Bull., 23: 1-38.

Chittenden, M.E. Jr. 1972. Responses of American Shad, *Alosa sapedissima*, to low temperatures. Trans. Amer. Fish. Soc., 101(4):680-685.

Embody, G.C. 1934. Relation of temperature to the incubation periods of eggs of four species of trout. Trans. Amer. Fish. Soc., 64: 281-292.

Ferguson, R.G. 1958. The preferred temperature of fish and their mid-summer distribution in temperate lakes and streams. J. Fish. Res. Bd. Can., 15: 607-624.

Garside, E.T. and J.S. Tait. 1958. Preferred temperature of rainbow trout (*Salmo gairdneri* Richardson) and its unusual relationship to acclimation temperature. Can. J. Zool., 36: 563-567.

Gibson, E.S. and F.E.J. Fry. 1954. Performance of lake trout, *Salvelinus namaycush* at various temperatures and oxygen levels. Can. J. Zool., 32: 252-260.

Graham, J.M. 1949. Some effects of temperature and oxygen pressure on the metabolism and activity of the speckled trout, *Salvelinus fontinalis*. Can. J. Res., 27: 270-288.

Grudniewski, C. 1961. /An attempt to determine the critical temperature and oxygen contents for fry of Wdzydze Lake trout (Salmo trutta morpha lacustris L.)/ (English summary) Rocz. Mauk Rolniczych, 93: 627-648.

Hart, J.S. 1947. Lethal temperature relations of certain fish in the Toronto region. Trans. Royal Soc. Canada, 41: 57-71.

Hildebrand, S.F. 1963. Family Clupeidae. Fishes of the Western North Atlantic. Mem. Sears Found. Mar. Res., 1(3): 257-442.

Horning, W.B., II and R.E. Pearson. 1973. Temperature requirements and lower lethal temperatures for juvenile smallmouth bass (Micropterus dolomieui). J. Fish. Res. Bd. Can., 30(8): 1226-1230.

Larimore, R.W. and M.J. Duever. 1968. Effects of temperature acclimation on the swimming ability of smallmouth bass fry. Trans. Amer. Fish. Soc., 97(2): 175-184.

Leach, G.C. 1923. Artificial propagation of brook trout and rainbow trout, with notes on three other species. Rept. U.S. Comm. Fish., (1923), Appendix VI: 1-74.

Leach, G.C. 1925. Artificial propagation of shad. Rept. U.S. Comm. Fish., (1924), Appendix VIII. Bur. Fish. Doc. 981: 459-486.

Lehmkuhl, D.W. 1972. Change in thermal regime as a cause of reduction of benthic fauna downstream of a reservoir. J. Fish. Res. Bd. Can. 29: 1329-1332.

Leim, A.H. 1924. Life history of the shad /Alosa sapidissima (Wilson)/ with special reference to the factors limiting its abundance. Contrib. Canadian Biology, NS. 2(11): 161-284.

Mansueti, R.J. 1955. Natural history of the American shad in Maryland waters. Maryland Tidewater News, 11(11, Supp. 4).

Massmann, W.H. 1952. Characteristics of spawning areas of shad, Alosa sapidissima (Wilson) in some Virginia streams. Trans. Amer. Fish. Soc., 81: 78-93.

Rayner, H.J. 1942. The spawning migration of rainbow trout at Skaneateles Lake, New York. Trans. Amer. Fish. Soc., 71: 180-183.

Sakowicz, S. and A. Stegman. 1961. /Rearing of Wdzydze Lake trout (Salmo trutta morpha lacustris L.) in ponds/. (English summary). Rocz. Nauk Rolniczych, 93: 751-770.

Spaas, J.T. 1961. Contribution to the comparative physiology and genetics of the European Salmonidae. III Temperature Resistance at different ages. Hydrobiologia, 15: 78-88.

Strawn, K. 1958. Optimum and extreme temperatures for growth and survival: various fishes. In "Handbook of Biological data".

Sullivan, C.M. and K.C. Fisher, 1953. Seasonal fluctuations in the selected temperature of speckled trout, Salvelinus fontinalis (Mitchill). J. Fish. Res. Bd. Can., 10: 187-195.

Svetovidov, A.N. 1963. Fauna of U.S.S.R. fishes. Volume II, No. 1. Clupeidae. Translation published by Nat. Sci. Foundation and Smithsonian Institute, 428 p.

Tagatz, M.E. 1961. Tolerance of striped bass and American shad to changes of temperature and salinity. U.S.F.W.S. Special Scientific Rept. 388. 8 p.

Trembley, F.J. 1960. Research project on effect of condenser discharge water on aquatic life. Inst. Res. Lehigh Univ. Prog. Rept., 1956-1959.

Chapter IV

Temperature Flow Relationships

Introduction

Initially an analysis of temperatures in the streams below Cannonsville and Pepacton Reservoirs was made based on streamflow and temperature records for the summer months of July and August for 1968 through 1971. The objective of the study was to examine the effect of reservoir releases on downstream temperatures during the critical summer months. Since the operation of the City Delaware Reservoirs changed significantly after the Cannonsville Reservoir became operational in March 1967, only the later years were considered.

The analysis provided some insight into the effect that increased flows from Pepacton and Cannonsville Reservoirs could have on the downstream temperatures in the East and West Branches Delaware River, respectively, and on the temperature at the Callicoon gage on the Delaware River. Unfortunately, the lack of variations in the flow regime precluded the establishment of any satisfactory temperature-flow relationship for the Neversink River.

West Branch Delaware River

During the two summer months, July and August, 1968 through 1971, the average daily water temperatures in the West Branch Delaware River at Stilesville varied from 5°C (41°F) to 10°C (50°F), generally associated with significant releases from Cannonsville Reservoir. The average daily stream temperatures downstream at Hale Eddy, varying from 8°C (46.4°F) to 25°C (77°F), were seen to be directly related to the water temperatures at Stilesville and thus correlated to the Cannonsville releases. Undesirable drastic changes in stream temperature of as much as 10°C (18°F) within a short period of time were recorded. About 15 percent of the time releases from Cannonsville were below 100 cfs, and more than 55 percent of the time the releases were above 1,000 cfs. The average summer temperature of the West Branch Delaware River at Hale Eddy dropped from 20.2°C (68.3°F) by about 3°C (8.4°F) when the Cannonsville release was increased from 23.1 cfs to 125 cfs (proposed conservation release) and by about 4°C (7.2°F) when the Cannonsville release was increased from 23.1 cfs to 190 cfs.

East Branch Delaware River

During the summer months of July and August, 1968 - 1971, the average daily water temperature in the East Branch Delaware River at Fishs Eddy varied from 20°C (68°F) to 29°C (84.2°F) when the releases from Pepacton were at the minimum level of 18.5 cfs. Releases of more than 100 cfs (up to 500 cfs) were recorded for less than 20 percent of the time. Temperatures below 13°C (55.4°F) at Fishs Eddy occurred rarely since such low temperatures are associated only with large releases from Pepacton Reservoir. The average summer temperature of the East Branch Delaware River at Fishs Eddy dropped from 22.6°C (72.7°F) by about 0.7°C (1.3°F) when the Pepacton release was increased from 18.5 cfs to 70 cfs (proposed conservation release), and by about 1.7°C (3.1°F) when the Pepacton release was increased from 18.5 cfs to 170 cfs. Thus, the increase in release by 100 cfs resulted in a decrease of average summer stream temperature at Fishs Eddy by only 1°C (1.8°F).

There were no temperature data available at the Harvard gage, upstream from Fishs Eddy, above the confluence of the Beaver Kill and East Branch Delaware River. Very limited temperature data were available at the Cooks Falls gage on Beaver Kill. During the study period, July and August, 1968 - 1971, only seven observations could be found. Therefore, a rigorous analysis could not be made to predict the variation of average summer stream temperatures at Harvard with releases from Pepacton Reservoir. A preliminary analysis was made using the seven observations at Cooks Falls to predict the approximate stream temperatures at Harvard. The results seem to indicate that the colder water released from the outlet of Pepacton Reservoir warms up as it flows towards Harvard depending on the quantity of release, flow from the drainage area above the Harvard gage and air temperature. On July 21, 1971, the release from Pepacton Reservoir was 159 cfs at 10°C (50°F) and the temperature at Harvard reached 23.3°C (73.4°F).

Delaware River

The average stream temperature at the Callicoon gage on the Delaware River ranged from 14°C (57.2°F) to 26°C (78.8°F) during the summer months of July and August, 1968 through 1971. The average summer temperature at Callicoon dropped from 25.4°C (77.7°F) by about 2.2°C (4.2°F) when the cumulative releases from Pepacton and Cannonsville Reservoirs were increased from 41.6 cfs to 195 cfs (cumulative proposed conservation releases) and by about 2.6°C (4.7°F) when the cumulative releases were increased from 41.6 cfs to 360 cfs.

The variation in instantaneous temperature with distance from Cannonsville Reservoir in the West Branch Delaware River to Hancock and the main Delaware River from Hancock to Callicoon indicated that the water temperature increased in the first few miles and remained steady to Hancock where the stream temperature gradually increased with distance. This could be due to the combined effect of warm water coming in from the tributary East Branch Delaware River and air temperature. A generalized curve showing the variation in average summer stream temperature with distance could not be developed due to the scarcity of field data. The temperature variation in general follows the air temperature variation. At points farther downstream the effect of reservoir releases on the water temperature was insignificant.

The type of existing reservoir outlet structures permits only the release of cold water from the lower strata of the reservoirs. When large volumes of such cold water are released from the reservoirs into the streams below, the average water temperature and its daily variation will both be reduced because of the increased heat requirements. Also,the water temperature changes will be smaller for increased and continuous reservoir releases. Therefore, the proposed conservation releases would prevent the water in the streams below the City reservoirs from becoming excessively warm and would limit the wide changes in stream temperatures as compared to the present situation with low conservation releases.

Thermal Flow Relationships

During the summer of 1975, the Division of Fish and Wildlife organized a field survey to collect stream temperature data at 37 stations on the West Branch, East Branch, Neversink and Delaware Rivers. Test releases from the City reservoirs required to collect data covering a significant range of variables could not be obtained. Also, it was not possible to use stations directly below Neversink, Cannonsville and Pepacton Dams due to a reluctance by the City to permit the monitoring crews to cross their property. Consequently,only baseline data on streamflow, water and air temperatures could be collected. There was practically no variation in release from Pepacton Reservoir. Release from Neversink Reservoir was only doubled during the period August 1 through September 15 on days when the Delaware River Master directed releases to meet the Montague flow requirement.

The above field data and the available historical data are being analyzed to develop mathematical models for four selected stations (Hale Eddy on the West Branch, Harvard on the East Branch, Woodbourne on the Neversink and Callicoon on the Delaware River). The models relate water temperatures at these stations to such relevant parameters as the reservoir release rate, upstream water temperature, flow from the tributary streams, and the prevailing atmospheric temperature. Since the models are difficult to visualize, three-dimensional graphics will also be prepared to illustrate them.

Using the above thermal flow relationships, investigations will be made of the Delaware Reservoir System's capability to provide release flows that will limit average water temperatures at the above four stations to 68°, 73°and 77°F.

Chapter V

Canoeing and Other Water Sports

Description

Canoeing and other water sports represent the focus of much of the commercial efforts on the Delaware and as such have been assessed in detail by a Barryville resident, Mr. Aaron Robinson. As a summer-long project for the New York State Law Department, Mr. Robinson evaluated businesses catering to the sports, access to the resources, present and future demands, and minimum water level needs for these sports.

Water sports utilizing the Catskill Rivers are becoming ever more popular. The wilderness setting, mountainous topography, challenging rapids, and secluded swimming spots make this region a favorite for hundreds of thousands of city dwellers seeking the outdoors. The "Forecast of Outdoor Recreation in New York State, 1970-1990" by the New York State Office of Parks and Recreation indicates that water sports will have the greatest increases within that period. Similar studies by the State of Pennsylvania have come to the same conclusion. Since the Catskills have these resources available, an even stronger influx of recreators is likely to occur here. An analysis by the New York State Department of Environmental Conservation shows that about 450,000 visitor days annually are devoted to swimming, picnicking, canoeing, camping and fishing in the reaches affected by the proposed conservation releases. An increase by the year 2000 to 610,000 visitor days is projected. This projection may be significantly conservative because there was no projected increase in canoeing demands, and a 14-week recreation season was used instead of the actual 22-week season. The DEC analysis resulted in estimated annual recreation user benefits of $1,222,000 in 1975 and $1,633,000 in 2000 for the affected reaches.

Canoeing

Among the various Delaware-based water sports, canoeing adds the highest per day dollar value to the region's economy. Costs to a canoeist include: boat rental or purchase, paddles, wetsuits, lifejackets, food and incidentals. Many of the purchases recur due to the damage the sport causes to equipment. Visitor day expenditures as high as $30 per day have been used for analysis purposes. Mr. Robinson's analysis indicates that about 1600 rental boats are now available with an annual 20 percent increase in inventory, according to local projections. At present, 16 liveries supply canoes, equipment, lodging and shuttle services during a 22-week season, generating about 100,000 user days. At $30 per day, the value of this pursuit to the local economy would be $3 million. There are 12 public access sites available and 22 private sites. Nine sports shops, 8 campgrounds, many restaurants, and numerous other businesses cater to canoeists. River-based recreation represents a multi-million dollar enterprise for this region.

The Delaware's 75 river miles between Hancock and Port Jervis abound with canoeing potential. Because of its rapids, wilderness areas, campsites and river access, the Delaware provides a unique experience to thousands of urban dwellers hungering for the thrill of outdoor adventure. Seven major rapids exist in this stretch which has a fall of 470 feet in elevation. Eighty-six percent of the land use along the river is forest, and many wilderness campsites exist on the river banks, with 730 camping sites off the river.

Canoeists have long considered the Upper Delaware as an attractive waterway because of its scenic topography, accessibility and isolation, and continuous length of free-flowing river. Through canoeing, individuals can interact with the environment and realize a keen sense of achievement. Since the challenge can be substantial, the surroundings invigorating, and the flowing water (when adequate) a psychological stabilizer, the prestige and satisfaction of river running is preferred by many recreationists. When the river is right, the experience is immeasureable; when the river is low, the experience is frustrating. Localities also sponsor regattas which motivate hundreds of competitors to race on the Delaware River during the summer.

Seventy-seven percent of the nation's canoeists originate in urban areas, one of the most significant of which is the New York City metropolitan area, only two hours from the Delaware River. Advertisements appear in New York City newspapers routinely for equipment rentals on the Delaware River. Guide books describe the Upper Delaware River as a highly scenic and challenging waterway. In addition to rented canoes, many families, individuals, and groups use their own canoes for recreation. Aerial surveys and spot checks indicate that 40 percent of the total use is non-rental and may increase as canoeing becomes more popular.

Problems

Although canoeing on the Delaware River is growing, the following problems plague its success:

1. Damage to canoes
2. Unsatisfied visitors and canoeists
3. Overcrowding on the river
4. Need for protection of the river corridors from litter, damage and inappropriate land use

The first two problems, canoe damage and unsatisfactory experiences are directly related to inadequate water levels Canoes require 5 to 7 inches of water, and this depth is not available along large stretches of the upper river during the summer. It is difficult to maneuver canoes, and a mid-stream portage is often needed. Also, about 10 to 20 percent of the rented canoes are damaged or destroyed annually as a result of collisions with rocks.

The third problem of overcrowding can be solved partially by the additional releases from the existing impoundments. Because of low water levels in the upper two segments of the river during the summer, canoeists are forced to crowd into the lower segment between Narrowsburg and Port Jervis. This short segment usually has extra flow from power releases in the Lackawaxen and Mongaup Rivers. This shift in river usage occurs after the spring runoff has stopped and is shown in Figure 7 based on data from aerial surveys made by DEC.

From June through August in 1974, Segment 1 had an average of 1.6 boats per mile; segment 2, 5.9 boats per mile; and segment 3, 11.8 boats per mile.. Similar trends have been noted in 1972, 1973, and 1975. The carrying capacity of the river as a whole would be significantly increased by the addition of many more miles of canoeable waterway made possible by the flexible release scheme. The carrying capacity of the river could be increased 300 percent without crowding by the addition of extra water. This increase would occur under the assumption that 12 boats per mile could be maintained throughout the three segments instead of the average of 4 boats per mile in 1974. Better distribution of canoes would also reduce fishermen complaints about canoeists.

The problem of protecting the river corridor has been considered by the Upper Delaware River Basin Board. In their tentative plan the Board recommends that a program be implemented as soon as possible to improve and control canoeing and other recreational uses of the Delaware River between Hancock and Port Jervis. The program could be developed and administered on an interim basis by New York and Pennsylvania or Sullivan County and then become a federal agency responsibility if the Delaware River is made part of the National System of Wild, Scenic and Recreational Rivers. Objectives of the program should include the following:

(1) limit the number of canoes and other recreational uses of the river at any one time to prevent overcrowding.

(2) provide basic camping and picnicking areas along the river with low cost sanitary facilities and trash receptacles.

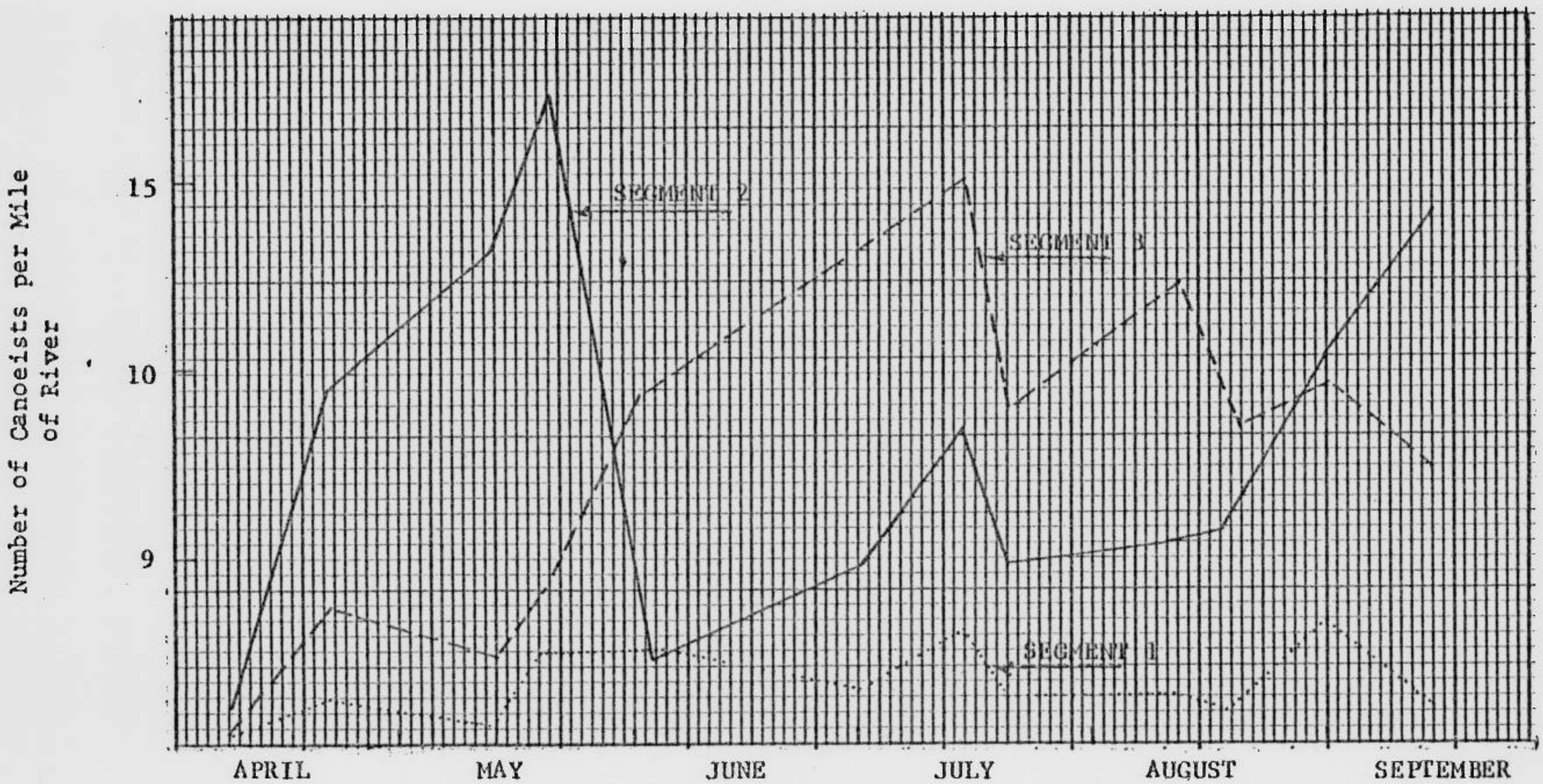
(3) preserve buildings and structures of historic significance along the river and convert some, where appropriate, into youth hostels

(4) encourage private livery operators to provide litter bags, river maps and instructions on proper use of the river and adjacent lands.

(5) establish standards, guidelines, and procedures for improving safety conditions on the river.

Water Flow Considerations

Certain relationships exist between the amount of water in the river and other physical characteristics, namely, wetted perimeter, cross-sectional area, depth, and velocity. Depending on the shape of the river's cross-section at the place in question, increasing the water flow, Q in cubic feet per second (cfs) will also increase all four other physical attributes as well.



SEGMENT 1 - Hancock to Callicoon
SEGMENT 2 - Callicoon to Narrowsburg
SEGMENT 3 - Narrowsburg to Port Jervis

CANOEING ON THE DELAWARE RIVER - 1974

FIGURE 7

For canoeing, maintenance of 5 to 7 inches in water depth is necessary. Cross-sectional areas determine the size of the environment for fish food and habitat. Assuming an adequate food source can live in the stream, a larger cross-section will support a larger fish population. The New York State Law Department undertook a computer study to relate various cross-sections of the rivers to the four attributes as shown in Table 3.

Table 3. Physical Characteristics in Relation to Flow, Delaware River at Callicoon, New York

River Level Q - cfs		Wetted Perimeter feet	Depth feet	Velocity feet/sec	Velocity mph	Cross-sectional Area square feet
A	445	256	1.8	2.25	1.5	200
B	995	376	2.46	2.48	1.7	401
C	1690	480	3.0	2.68	1.8	630
D	2510	533	3.5	2.93	2.0	857

If 1000 cfs at Callicoon were maintained during the canoeing season, as recommended by the proposed agreement, the promise of the Delaware canoeing potential could be realized. Difficulties with portages, boat damage, and dry river beds occur with the frequency shown in Table 4, often representing the majority of days during the summer months.

Table 4. Number of Days During Month Delaware River Flow Was Below 1000 cfs at Callicoon or 1040 cfs at Barryville

	JUNE		JULY		AUGUST	
	Callicoon	Barryville	Callicoon	Barryville	Callicoon	Barryville
1972	0	0	9	9	18	16
1973	0	0	12	8	25	15
1974	11	3	9	7	21	21
1975 1/	2	0	9	18	2	16

1/ after 6/25

An increase from the 500 cfs natural flow at Callicoon to 1000 cfs will raise the water level approximately 7 inches, well over the draft requirements of a loaded canoe Similar improvements would occur at other critical areas where canoes are often grounded at low water. At Barryville, maintenance of 1040 cfs (implicit in maintenance of 1000 cfs at Callicoon) will insure canoeing success on many days each year considered marginal at the levels now experienced due to present reservoir operating regimes. It should be noted here that because of the Montague formula mandated by the U. S. Supreme

Court Decree of 1954, excess releases called for by the river master will continue to diminish, further exacerbating the problems now plagueing the river's uses.