Effects of Storage and Mainstream Reservoirs on Benthic Macroinvertebrates in the Tennessee Valley

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Abstract

Studies involving benthic macroinvertebrates in the Tennessee Valley region have generally shown that benthic fauna may be limited by siltation, rheotactile deprivation, water level fluctuation, increased hydrostatic pressure, light, and most pertinently by hypolimnetic oxygen deficiency in the storage impoundments.

The short plankton-to-fish food chain is characteristic of Valley storage impoundments and to some extent of flow-through reservoirs. Despite loss of benthic fauna, the Valley impoundment fishery is now at least fifty times that of the unimpounded river.

Benthic fauna is of little importance in TVA storage impoundments. Limited benthic fauna below some storage impoundments has been attributed to seasonally low oxygen tension. Benthic fauna below most mainstream flow-through impoundments is typically rheophilic, including mussels, residual populations of snails (Pleuroceridae), sponges, bryozoa, and insects.

Decline in numbers of species of mussels (Unionidae), especially Cumberlandian forms, has been associated with impoundments. Few Unioninae but significant numbers of Anodontinae and Lampsilinae have been able to colonize postimpoundment mud-sand shallows of flow-through impoundments.

Decline in snail *(Io)* populations in the eastern Valley and pleurocerid populations throughout the Valley is associated with habitat alteration as a result of impoundment.

Introduction

Numerous papers have been addressed to the effects of impoundment on water quality and fisheries in the Tennessee Valley. Work on benthic macroinvertebrates has been cursory or secondary to fisheries investigations for the most part. Wiebe (1958) briefly discussed the effects of impoundment upon benthic macroinvertebrates in the Tennessee River system. This paper brings together some of the pertinent works that have been addressed to analysis of benthic macroinvertebrates in the Tennessee Valley over the past 50 years.

Effects of impoundment on faunal assemblages and changes in the relationship between structure and function in the aquatic environment resulting from impoundment are discussed. Effects of impoundment on the fauna in the Clinch River above and below Norris Dam are considered as a model of Tennessee

Valley Authority (TVA) storage impoundments and their effluents. Effects of mainstream impoundments on the original endemic molluscan fauna are considered representative of this type of habitat alteration.

Preimpoundment Studies

Published reports specifically on preimpoundment bottom fauna have been prepared only for Watts Bar and Cherokee Reservoirs, but considerable data exist in unpublished form and in restricted faunistic studies.

The aquatic Mollusca in the Tennessee Valley and contiguous regions have been studied extensively. T. A. Conrad (1834), according to Ortmann (1924), observed the extensive mussel fauna at Muscle Shoals on the Tennessee River in Alabama. An excellent paper on a benthic group is "Variations and Ecological Distribution of the Snails of the Genus *Io*" which was compiled by Adams (1915).

Ortmann (1918) reported 44 mussel species in collections from the Clinch River below the present Norris Dam site and above Clinton, Tennessee, (Moore Ferry). Collections from Edgemoor, mile 47.8 (now in Melton Hill Reservoir), Anderson County, Tennessee, contained 34 species of mussels. Ortmann collected at other stations in the upper east portion of the Tennessee River basin. Most of the endemic molluscan fauna reported by Ortmann have been annihilated either by pollution or by impoundments or possibly by a combination of events. He also noted in this paper that the Tennessee Valley region was a chief center of mussel development and an area better represented by this group than any in the world. Conrad, Lea, and others (Ortmann, 1918) described many species that originally came from this region. He recorded sources of pollution affecting mussels at Saltville, Virginia; Asheville and Canton, North Carolina; and Tellico Plains, Tennessee. He also speculated that the effect of dams, such as the one on the Nolichucky River at Greeneville, Tennessee, would have an ever-increasing deleterious effect on mussel populations.

Ellis (1931), in reporting work for 1930 and 1931, noted the extent to which mussels were affected by siltation caused by temporary and permanent obstructions of streamflow. However, he noted that where wing dams or other obstructions of flow were present there was accelerated siltation caused by slower stream velocity behind the obstruction and changes in water current patterns, resulting in further undercutting of banks and channels. Siltation during this period was much greater than it is presently.

Ellis (1936) reported that dams sufficiently large to create deep pools with low current velocity may result in thermal and silt stratification in summer. He measured the millionth intensity depth (m.i.d.) or point at which light would be reduced to one-millionth of its surface intensity in Wilson Reservoir, Alabama, Tennessee River, and illustrated the definite stratification of silt due to impoundment. Measurements on August 24, 1931, showed that a vertical distribution of silt measured in terms of m.i.d. was as follows: 1,147 mm at surface; 1,070 mm at a depth of 15 meters; 1,127 mm at 18 meters or the bottom of the epilimnion; 4,143 mm at 21 meters; and from the 24th meter level to the bottom, clear water with 7,860 mm. He concluded that erosion silt alters aquatic environments by screening out light, affecting heat radiation, blanketing the bottom, and retaining organic material and other substances which may affect benthic fauna.

Hickman (1937) recorded the numerous species of mussels and snails in the Norris Dam site area of the Clinch River with special attention to snails of the genus *Io*. She predicted that the Norris Dam flood control project would have a deteriorating effect on the molluscan fauna, and there are no postimpoundment records of *Io* in the area she studied.

Following closure of Norris Dam on

March 4, 1936, A. R. Cahn collected mussels extensively below Norris Dam in the dewatered riverbed. Between March 4 and June 1, 1936, he identified 45 species of pelecypods (unpublished TVA report) and obtained data on abundance of 9 species (Table 1). The preimpoundment molluscan fauna both above and below Norris Dam represented a "saturated population density" or a density limited primarily by food supply. When the water was again at low stage, 4 months later, not a single mussel specimen could be found in the study area.

Tarzwell (1938) reported on the benthos changes in the Clinch River below Norris Dam following closure. He noted that water released from the dam in June had a temperature of 8.9° C (48° F) rather than in the 26.7° C (80° F) range attained prior to impoundment. Benthos density below Norris Dam was small in comparison with the more productive trout streams. Most significant was the lack of organisms considered to be suitable trout food. He noted the rarity of caddisflies, mayflies, stoneflies, and dragonflies which indicated that the Clinch River had not developed a typical trout stream bottom fauna. Snails were abundant in his samples and accounted for 97% of the biomass. All other organisms constituted 93% of the total population number but only 3% of the total weight of bottom organisms. Standing crop of bottom fauna, exclusive of snails, averaged 5.5 kg per ha. He noted an average number of 406 organisms per 0.093 sq m (1 sq ft), including snails, for all samples taken.

Table 1.—Areal density of nine selected species of mussels below Norris Dam[1]

Species	Average/30.48 m (100 ft) river
Amblema (costata) plicata (Raf.)	88
Quadrula metanevra (Raf.)	82
Cyclonaias tuberculata (Raf.)	74
Pleurobema cordatum (Raf.)	132
Actinonaias carinata (Barnes)	121
Ligumia recta latissima (Raf.)	76
Lampsilis ovata (Say)	91
Lampsilis (ovata) ventricosa (Barnes)	83
Lampsilis orbiculata (Hildreth)	68
Total	815

[1] Modified from unpublished TVA report by A. R. Cahn (1936).

Pfitzer (1962) examined the area below Norris Dam in 1951 and reported an average of 40 organisms with a volume of 0.90 cc per sq ft. He noted, with reference to food habits of fish, that the Norris tailwater provided a monotonous diet for a mature tailwater. Norris is the oldest of Valley cold-water tailwaters with a 0.038 m/km gradient (2 ft/mi). Only a few small invertebrate species have replaced its original bottom fauna.

Benthic samples typical of that section of the river contained *Lirceus* sp. which was the most important fish food organism apart from algae *(Cladophora crispata)* (Tables 2 and 3). Pfitzer (1954) noted a limited amount of rainbow trout reproduction by return of only 10% to 15% fin-clipped to non-fin-clipped fish of 500,000 fingerlings clipped and released. He indicated that reproduction apparently occurred in small streams tributary to the tailwaters rather than in the tailwaters below the impoundments studied. A reproducing population of trout has not become established in the Norris Dam tailwater despite considerable effort through the years (personal communication with Tennessee Game and Fish Commission).

Elder (1969) reported blackflies (Simuliidae) and midges (Chironomidae) as the only abundant trout stream forms in the Norris Dam tailwater. The lack of typical trout stream macroinvertebrates in the Norris Dam tailwater was attributed to insufficient oxygen—often less than 4 ppm and as low as 0.5 ppm. The low dissolved oxygen (D.O.) in the tailwater is associated with hypolimnetic oxygen deficiency in Norris Reservoir.

Lyman (1943) conducted a preimpoundment bottom-fauna study of the Watts Bar area, Tennessee River, Tennessee. The study was designed to de-

Table 2.[1] *—Number and volume of bottom organisms,*[2] *Norris tailwater station 1,*[3] *1951.*
(Numbers in parentheses indicate volume in cubic centimeters)

1951	Plecoptera	Ephemeridae	Tendipedidae	Isopoda	Gastropoda	Total	Average per square foot	Average per square meter
Jan.	5 (.2)	14 (.5)	76 (.3)	64 (2.0)	7 (.6)	162 (3.6)	40 (.90)	430 (9.7)
Feb.	13 (.4)	26 (1.1)	82 (.3)	76 (2.5)	9 (.8)	206 (5.1)	51 (1.27)	549 (13.7)
Mar.	6 (.2)	18 (1.0)	54 (.2)	224 (5.9)	24 (2.2)	326 (9.5)	81 (2.37)	872 (26.0)
Apr.	0 (0)	3 (—)	136 (.6)	193 (5.0)	3 (.1)	335 (5.7)	84 (1.42)	904 (15.3)
May	8 (.3)	7 (.1)	214 (1.1)	171 (5.1)	14 (1.1)	414 (7.7)	103 (1.92)	1108 (20.7)
June	9 (.3)	23 (.8)	59 (.2)	210 (6.5)	8 (.9)	309 (8.7)	77 (2.17)	829 (23.3)
July	0 (0)	13 (.5)	88 (.4)	48 (1.5)	6 (.5)	155 (2.9)	39 (.72)	420 (7.7)
Sept.	16 (.5)	79 (.3)	79 (.3)	236 (6.9)	12 (1.0)	365 (9.6)	91 (2.40)	979 (25.8)
Oct.	7 (.2)	128 (.6)	128 (.6)	78 (2.5)	14 (1.2)	229 (4.5)	57 (1.12)	613 (12.1)
Nov.	8 (.2)	171 (.8)	171 (.8)	51 (1.6)	21 (1.9)	260 (4.9)	65 (1.22)	699 (13.1)

[1] Modified from Pfitzer (1962).
[2] Each sample represents four bottom samples of one square-foot each. Volumes less than 0.1 cc are not included.
[3] Near mouth of Mill Creek (probably Clear Creek) approximately 1.5 miles below dam.

termine bottom fauna potentially available as fish food in the lotic environment to be included in the mainstream Watts Bar Reservoir (Table 4) for comparison with fauna found in a preimpoundment study on the Holston River which was flooded by Cherokee Dam, a storage impoundment (Table 5).

Ephemeroptera, Diptera, Oligochaeta, and Anisoptera made up 99% of the total number and essentially 100% by volume of 12 taxonomic categories found in deep-water samples taken in the Watts Bar area, Tennessee River. These taxonomic groups constituted 86% of the total number of organisms and 90% of the total volume at a shallow-water station. The former percentage was based on 122 Petersen samples and the latter on 106 Surber samples (Table 4).

Ephemeroptera were numerically dominant in both habitats, *Hexagenia bilineata* in deep water and Heptageniidae and Baetidae in shallow water. Lyman (1943) predicted that, since Watts Bar Reservoir would be a flow-through type, *Hexagenia* nymphs would survive and flourish under the new and more favorable impoundment conditions. Smith and Isom (1967) reported principal components of the Watts Bar postimpoundment benthic fauna were *Hexagenia* along with Chironomidae, Heleidae, *Chaoborus*, oligochaetes, and Asiatic clams *(Corbicula)*.

Lyman and Dendy (1945) hypothesized that, since the Cherokee area preimpoundment fauna was of a shallow-water riffle type and the Watts Bar area fauna was in part a deep-water type, impoundment would adversely affect the Cherokee fauna and enhance production of the Watts Bar fauna. This was essentially the situation in 1970.

Samples taken in the Clinch River above the influence of Norris Reservoir in June 1967 are probably minimally representative of the preimpoundment fauna (Table 6). Samples from the Powell River, also above Norris Reservoir, represent a typical rheophilic fauna (Table 7).

Ortmann (1925) made extensive ob-

Table 3.—Contents of stomach samples of rainbow trout collected in Norris Dam tailwater during 3.5-year period, 1951-1954. The figures are the percent composition by number of total organisms per stomach[1]

Organisms	Number of stomachs and months collected 15 Dec.-Feb.	12 Mar.-May	28 June-Aug.	15 Sept.-Nov.
Tendipedidae	38.5	41.3	32.6	37.9
Isopoda	46.0	48.1	57.4	50.6
Snails	15.0	6.0	3.1	9.4
Ephemerids	0.0	0.2	0.0	0.0
Plecoptera	0.0	0.1	0.1	0.0
Fish	0.1	0.2	0.1	0.0
Terrestrial	0.4	4.1	6.7	2.1
Algae[2]	(85.0)[3]	(45.0)	(35.0)	(75.0)

[1] From Pfitzer (1962).
[2] Approximate percentage of volume of total bulk per stomach.
[3] *Cladophora crispata* and *Ulothrix zonata* were the principal forms found in the tailwater.

servations of the lower Tennessee River mussels but did not generally relate findings to ecological conditions. Van der Schalie (1939) anticipated that impoundment would affect Tennessee River mussels if the native mussel population's reaction was similar to that of mussels found in other ponded areas.

Ortmann (1918, 1925), Van der Schalie (1939), Scruggs (1960), Bates (1962), Stansbery (1964), Isom (1969), Isom and Yokley (1968, 1968a), and Sinclair (1969) are references to the historical and current status of the Tennessee River molluscan fauna.

Table 4.[1] *—Abundance of major taxonomic groups, Watts Bar Reservoir area, 1941*[2]

Organisms	Percent of total number in deep water	shallow water
Nematoda (Roundworms)	0.14	0.45
Oligochaeta (Earthworms)	13.86	1.39
Hirudinea (Leeches)	0.02	12.98
Decapoda (Crustacean)	Trace	0.07
Hydracarina (Water mites)	0.08	—
Sialidae (Dobson-flies)	0.02	2.33
Ephemeroptera (Mayflies)	64.10	33.61
Anisoptera (Dragonflies)	1.54	0.85
Zygoptera (Damselflies)	0.02	3.01
Coleoptera (Beetles)	0.59	5.25
Trichoptera (Caddisflies)	0.20	22.33
Diptera (True flies)	19.43	17.35
Total	100.00	100.00

[1] From Lyman (1943).
[2] Exclusive of mollusca.

Postimpoundment Studies

Effects of impoundment on physical and chemical qualities of waters in the Tennessee Valley have been documented in numerous reports: (Wiebe, 1938, 1939, 1939a, 1940, 1940a, 1941; Churchill, 1958; Dendy, 1946; and Eschmeyer, 1939, 1950). This information has not been specifically related to changes in benthic macroinvertebrate population density or composition. Wiebe (1938) noted the absence of immature stages of insects, *Ephemera*, Odonata, Trichoptera, and Coleoptera, in Norris Reservoir. He noted the presence of *Chironomus* larvae and larval *Corethra* which were abundant on the bottom in deep water. Some aquatic worms were collected at depths of 44 m (140 ft) to 61 m (200 ft) in Norris Reservoir in 1937. Ostracods were the only organisms noted in shallow-water bottom samples taken in depths of 3 m (10 ft) to 12 m (40 ft).

Table 5.[1] *—Abundance of major taxonomic groups, Holston River Mile 65.1 in 1941 preimpoundment samples; Cherokee Reservoir*[2]

Organisms	No./0.093 sq m (1 sq ft)	Percentage of total number
Turbellaria (Flatworms)	0.24	0.1
Nematoda (Roundworms)	0.17	Trace
Oligochaeta (Earthworms)	2.39	0.6
Hirudinea (Leeches)	0.01	Trace
Hydracarina (Water mites)	0.01	Trace
Sialidae (Dobson-flies)	2.07	0.5
Ephemeroptera (Mayflies)	14.97	3.5
Anisoptera (Dragonflies)	0.10	Trace
Zygoptera (Damselflies)	0.69	0.2
Plecoptera (Stoneflies)	0.04	Trace
Coleoptera (Beetles)	9.81	2.3
Trichoptera (Caddisflies)	269.26	63.4
Lepidoptera (Aquatic caterpillars)	0.01	Trace
Diptera (True flies)	125.01	29.4
Total	424.78	100.0

[1] After Lyman and Dendy, 1945.
[2] Based on 157 square-foot Surber samples.

Wiebe (1938) observed that dissolved oxygen concentrations approached zero in late summer in Norris Reservoir as a result of movement of "stagnant water" below the surface from the head of the reservoir toward the dam. Subsurface movements were accelerated by drawdown, and these physical and chemical changes could result in loss of significant benthic faunal elements. Wiebe (1939) noted that D.O. deficiency in Norris Reservoir and its Big Creek sector was due to B.O.D. of the water at the head of the reservoir causing D.O. depletion within the hypolimnion (Figure 1). His laboratory tests in 1938 showed that in water taken toward the head of Norris Reservoir, where depth was about 15 m

Table 6.—Clinch River benthic fauna number (June 26, 1967) from data furnished by the Tennessee Game and Fish Commission. Figures in parentheses are the number of organisms per 0.093 sq m (1 sq ft)

Organisms	Bacon's Ferry	Briar Creek	War Creek	Lawson's Mill	% of Total
Ephemeroptera	1 (0.5)	50 (16.7)	17 (5.7)	97 (48.5)	44.5
Trichoptera	6 (3.0)	13 (4.3)	—	45 (22.5)	17.2
Plecoptera	3 (1.5)	2 (0.7)	—	4 (2.0)	2.4
Odonata	—	—	—	1 (0.5)	0.2
Neuroptera	—	—	—	1 (0.5)	0.2
Diptera	46 (23.0)	21 (7.0)	—	17 (8.5)	22.7
Coleoptera	10 (5.0)	8 (2.7)	1 (0.7)	8 (4.0)	7.1
Lepidoptera	—	—	—	1 (0.5)	0.2
Annelida	—	1 (0.3)	3 (1.0)	—	1.8
Gastropoda	6 (3.0)	1 (0.3)	—	5 (2.5)	3.2
Pelecypoda	—	—	—	2 (1.0)	0.5
Total	72 (36.0)	96 (32.0)	21 (7.0)	181 (90.5)	100.00

Table 7.—Powell River benthic fauna number per 0.093 sq m (1 sq ft)[1]

	Powell River Mile				
Organisms	106.6	130.3	155.0	165.0	175.0
Decapoda	—	—	0.5	0.5	1.0
Pleurocera	0.5	7.0	—	1.5	0.5
Viviparus	15.0	3.0	—	—	—
Ancylidae	0.5	1.5	26.0	—	—
Tubificidae	—	—	1.0	1.0	—
Sialidae	0.5	—	3.5	—	0.5
Chironomidae	—	0.5	24.5	—	21.0
Simulidae	0.5	0.5	—	—	—
Rhagionidae	—	—	5.0	—	4.5
Psephenidae	—	—	0.5	—	2.5
Elmidae	0.5	0.5	16.5	2.0	1.0
Aeschnidae	0.5	0.5	—	—	—
Baetidae	3.0	9.0	4.5	1.5	0.5
Heptageniidae	13.0	5.5	13.0	13.5	7.0
Hydropsychidae	17.0	13.5	294.0	3.0	0.5
Total	51.0	41.5	389.0	23.0	39.0

[1] Modified from Anon. TVA Report (1970).

(50 ft), D.O. demand was sufficient to utilize all of the O_2 in the water column in a few days (Table 8).

Wiebe (1941) reported observations on Norris Reservoir which showed that game fishes are vertically oriented in relation to density currents associated with stagnant water. He reported mortality of fish in Norris Reservoir during the summer of 1937 resulting from hypolimnetic oxygen deficiency. D.O. depletion from July to October would be sufficient to preclude benthic invertebrates from surviving or colonizing substrate in the preimpoundment habitats now inundated, except seasonally.

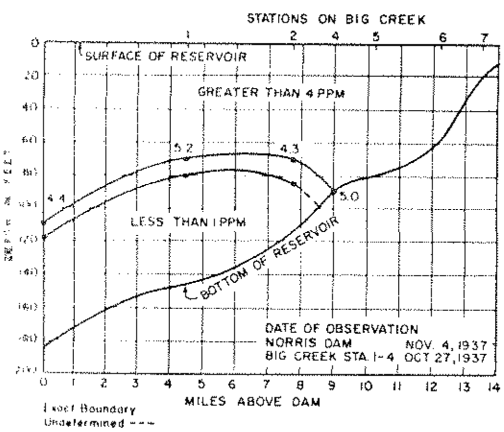

Figure 1. Dissolved oxygen profile, Norris Dam and Big Creek, Tennessee (from Wiebe, 1939).

Eschmeyer (1939) found that four principal piscivorous fishes in Norris Reservoir—largemouth bass, smallmouth bass, Kentucky bass, and walleye—showed rapid growth rates between the 1938 and 1939 growing seasons. He hypothesized that poor bluegill growth was due to lack of insect life as a result of water level fluctuation.

Reporting on food habits of fish in Norris Reservoir, Dendy (1946) noted that benthic invertebrates were of little importance in the food chain; plankton-to-fish is the common storage impoundment food chain. The fish food chain was short because of the lack of aquatic vegetation and associated biota along the reservoir margins. Annual water level fluctuations varied from 60 to 80 ft (18.3-24.4 m). Eschmeyer (1950) attributed lack of extensive bottom fauna to winter drawdowns of storage reservoirs. This condition would be found only in the postimpoundment overbank substrate of shallower areas.

Table 8.—Dissolved oxygen values for samples collected at Big Creek No. 8 on June 28, 1938. At the same time three sets of samples were placed in a dark compartment on the laboratory boat and tested for D.O. as indicated in columns 2 to 4. One set of these samples (column 4) had formalin added as a preservative. All incubated samples were subject to changes in temperature[1]

Depth, feet	Initial D.O. 6/28/38	D.O. left 7/12/38	D.O. left 7/29/38	D.O. left in preserved samples[2] 7/29/38
1	8.8 p.p.m.	3.1 p.p.m.	0.00 p.p.m.	6.0
5	8.1	2.7	0.00	6.0
10	7.2	2.4	0.48 ?	5.8
15	4.9	0.5	0.00	3.6
20	3.1	0.5	0.00	2.4
25	2.0	0.05	0.00	1.32
29 (b)	1.4	0.00	0.00	0.9

[1] From Wiebe (1939).
[2] It is possible that not enough preservative had been added. Still there is a marked difference between D.O. values in columns 3 and 4.

Eschmeyer (1950) also noted that the food chain in storage impoundments does not rely on bottom food but on planktonic organisms. Gizzard shad *(Dorosoma cepedianum)* and threadfin shad *(D. petenense)* are the primary forage species in Norris Reservoir and similar storage impoundments in the Tennessee Valley. Young crappie, bluegill, and bass are also utilized by larger piscivorous species in Norris Reservoir.

Fitz (1968) attributed the changes in the fish population composition of the Clinch River, Melton Hill Reservoir area, to impoundment. He reported that of a total of 60 species, 35 species occurred both before and after impoundment, 12 before impoundment only, and 13 after impoundment only. Preimpoundment benthic samples were not taken; therefore, correlation between fish population composition change and benthic fauna cannot be made. Only a few post-impoundment invertebrate fauna were reported.

The most important benthic group in the Tennessee River system, mussels or naiads, has been reduced from approximately 100 species to nearly one-half that number (Isom, 1969). The formerly abundant species *Fusconaia ebenus* and *Pleurobema cordatum* were the basis of a significant mussel industry in the 1950s and early 1960s, yielding about 9,090 MT (10,000 tons) annually (Isom, 1969). Since 1963, the annual harvest has been near 1,818 MT (2,000 tons) with *F. ebenus* and *P. cordatum* becoming progressively more scarce.

The most significant changes in composition and distribution of mussel populations since impoundment have been the invasion of postimpoundment habitats by Anodontinae and Lampsilinae and the progressive loss of riverine mussels (Unioninae) in the reservoir (Bates, 1962; Isom, 1969). Sinclair (1969) noted that of the original pleurocerid fauna only three species remain of seven (five genera) present before impoundment of the Tennessee River. Scruggs (1960) stated that factors limiting natural replacement of mussel stocks in the lower Tennessee are changes in fish-host associations involved in the complex life histories of the mussels and siltation in the reservoir after impoundment.

Bates (1962) compared the preimpoundment and postimpoundment mussel fauna of Kentucky Reservoir. Only one species *(Quadrula quadrula)* of

Unioninae, a formerly dominant group, has inhabited postimpoundment shallows along with Lampsilinae and Anodontinae. The latter was observed to have "ecological preference" for soft substrates. Bates noted that normal mussel reproductive activity was apparent but that lotic to lentic transition with attendant increase in siltation, hydrostatic pressure, rheotactile deprivation, and possible decrease in O_2 tension "... may have doomed to slow extinction the preimpoundment assemblage of species inhabiting the 'old' river channel."

Isom (1969) noted the presence of two additional Unioninae (*Megalonaias gigantea* and *Amblema plicata*) in postimpoundment mud-sand shallows. Stansbery (1964) observed the susceptibility of Cumberlandian mussel species to changes in the aquatic environment associated with impoundment of the river at Muscle Shoals. Isom (1969) noted the effects of sediment in concert with overharvest on decline of commercial mussel species in the Tennessee River. Athearn (1967) associated decline in east Tennessee-area molluscan populations with pollution and rheotactile deprivation.

Sinclair and Ingram (1961) reported the presence of *Corbicula manilensis* Philippi (Asiatic clam) in the Tennessee River from samples taken October 21, 1959. Since that date, *Corbicula* has been the most successful invader of flow-through impoundments in the Tennessee Valley and occupies essentially the entire length of the Tennessee River. Many of the tributaries to the Tennessee also have *Corbicula*, including Indian Creek, Alabama (Isom, 1968), Bear Creek, Alabama (Isom and Yokley, 1968), Duck and Buffalo Rivers, Tennessee (Isom and Yokley, 1968a), and Elk River drainage (personal observation). *Corbicula* has proved to be a pest in some industrial water supplies (Sinclair and Isom, 1961, 1963; Sinclair, 1964), but is utilized as food by many fishes.

Mullican et al. (1960) presented a lengthy list of typically rheophilic fauna found in the Nolichucky River, Tennessee, a tributary to Douglas Reservoir. Although various types of gross pollution were observed, the faunal diversity in this stream is significant. Patrick (1961) reported the rheophilic fauna from the headwaters of North Holston River, Smyth County, Virginia. Unfortunately, except for records of Mollusca, benthic faunal lists are generally lacking for larger Valley streams.

Chaoborus and the limnetic cladoceran [*Leptodora kindtii* (Focke)] are common in many of the mainstream reservoirs in the Tennessee River (Isom and Sinclair, 1963; personal observations) and may suffice as replacement of benthic fauna in the food requirements of some fish species, especially their fry.

A sessile coelenterate (*Cordylophora lacustris* Allman) inhabits many of the postimpoundment lower mainstream reservoirs in the Tennessee River and the Cumberland and Duck Rivers in Tennessee (Isom and Sinclair, 1962). Berg (1948), as recorded by Isom and Sinclair (1962), associated the spread of *C. lacustris* with building of locks and subsequent river commerce. The author has observed passive transport of *Corbicula* in barged gravel on both the Tennessee and Cumberland Rivers. Since gravel, stones, and bedrock are the most common habitats of *C. lacustris* transportation of this type of material by barging seems the most likely means of its spread.

Sinclair and Ingram (1961) presented benthos data from Pickwick Dam tailwater which is typically rheophilic and is representative of benthos composition below mainstream dams on the lower Tennessee River (Table 9).

Wiebe (1958) detailed many benefits of impoundments including the fact that the impoundment fishery in TVA reservoirs is now at least fifty times that of the unimpounded river, although increase in surface area is only about sixfold that of the preimpoundment streambed.

Table 9.—Benthos from Pickwick Dam tailwater, Tennessee River.[1]
A = abundant; C = common; F = few

Organisms	206.3 Power Line[2]			205.3[2]			203.3[2]		
	Left	Mid	Right	Left	Mid	Right	Left	Mid	Right
Zoothamnium	F								
Dendrosoma	C								F
Spongilla fragilis								A	
Trochospongilla leidyi	C			C					
Unidentified sponge					F			A	
Cordylophora lacustris		F		F	A	A			
Dugesia tigrina	5		2	4	4	6	14		19
Urnatella gracilis	C	C	C	C	F		F		F
Paludicella articulata	C			F	F	F	F		F
Fredericella sultana	C								
Pristina							1		
Nais communis				1		1		7	
Paranais									
Unidentified leech									1
Unidentified beetle			1						
Chaoborus punctipennis					1				
Hydrobaenus sp. A	31	47	5	9	117	68	1	26	4
Cricotopus bicinctus						1			
Unidentified *Tendipedini*								1	
Harnischia sp. A		5	2		29	2	1	8	
Tendipes nervosus	1				4	15		2	1
Tendipes modestus	59	14	16	7	12	7	1		3
Polypedilum sp. B									1
Calopsectra exigua			2	5	3	48	3	169	101
Trycorythodes	1			1			1		1
Stenonema				1					
Agraylea			2				1		
Athripsodes				2					
Potamyia flava				41		44	19	131	234
Hydropsyche orris				141		17	2	3	11
Cheumatopsyche		1		4	5	43		30	13
Psychomyiidae Genus A	51	22	21	30	54	92	11	193	21
Lithasia verrucosa									1
Ferrissia shimekii				4		33	7	5	19
Quadrula sp.						1	1		
Quadrula tuberculata						2			
Corbicula fluminea	4	1	5	11		1	77		7
Total	152	90	56	261	229	381	141	575	437
Transect totals		298			871			1,153	

[1] Modified from Sinclair and Ingram (1961).
[2] Miles from mouth of river.

Summary

Although the preimpoundment faunistic studies available are limited, they are sufficient for comparison with postimpoundment studies to show some effects of impoundment on benthic macroinvertebrates.

Studies have shown that benthic macroinvertebrates may be limited by siltation, rheotactile deprivation, water level fluctuation, hypolimnetic oxygen deficiency, increased hydrostatic pressure, light, and other impoundment-associated factors. Virtually all benthic fauna has been eliminated from storage impoundments in the Valley but some seasonal colonization of shallow overbank areas has occurred.

Benthic fauna below mainstream impoundments is typically rheophilic and includes mussels and residual populations of Pleuroceridae.

The short plankton-to-fish food chain is characteristic of storage impoundments and to some extent of mainstream reservoirs.

Limited benthic fauna below some storage impoundments has been attributed to seasonally low oxygen tension.

Recent decline of mussel populations is attributable to impoundment and overharvest. Few Unioninae but significant numbers of Anodontinae and Lampsilinae have been able to colonize postimpoundment mud-sand shallows. Change in fish-host associations involved in the complex life histories of the mussels is deemed to be responsible in part for decline of Unionidae.

Decline of snail *(Io)* populations in the upper Tennessee River drainage and of Pleuroceridae throughout the Valley is associated with habitat alteration as a result of impoundments.

The accidentally introduced Asiatic clam (*Corbicula manilensis* Philippi) has been a pest in some instances but is utilized by a number of faunal associates. It has been the most successful invader of impoundments on the Tennessee River and some of its tributaries.

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